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Total Petroleum Hydrocarbon (TPH) Criteria Working Group Field Demonstration Project: Tinker Air Force Base, Oklahoma

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TECHNICAL REVIEW AND APPROVAL

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This technical report has been reviewed and is approved for publication.

FOR THE DIRECTOR

//SIGNED//

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Deputy Chief, Biosciences and Protection Division
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14. ABSTRACT
Site 21 at Tinker Air Force Base, Oklahoma was selected as a demonstration site for the Total Petroleum Hydrocarbon Working Group approach for establishing Risk Based Screening Levels. The site had been previously characterized using conventional analyses and was recommended for natural attenuation. Contaminants included JP-4 and diesel fuels. Groundwater and soil samples were collected and analyzed using the Direct Method, specified by the Working Group. A Tier 1 risk assessment was performed to determine clean-up levels. Average site concentrations did not exceed the average Risk Based Screening Levels. The bulk of the contaminated soil has not weathered significantly, but the recommendation for natural attenuation was confirmed.

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PREFACE

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

°C	degrees Celsius
μg	microgram
AFB	Air Force Base
AFRL/HEST	Air Force Research Laboratory, Operational Toxicology Branch
ASTM	American Society for Testing and Materials
atm	atmosphere
BGS	below ground surface
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
cm	centimeter
C_{sat}	saturation Concentration
DRO	Diesel Range Organics
EC	Effective Carbon number of chemical molecule
EPA	U.S. Environmental Protection Agency
ft	feet
g	gram
GC	Gas Chromatograph
GRO	Gasoline Range Organics
H_c	Henry's Law Constant
HI	Hazard Index
HQ	Hazard Quotient
ISGC	Investigation for Soil and Groundwater Cleanup
kg	kilogram
L	liter
LOQ	Limit Of Quantitation
mg	milligram
mol	mole
MSL	Mean Sea Level
NAPL	Non Aqueous Phase Liquid
ND	Nondetect
OC-ALC/EMR	Oklahoma City Air Logistics Center, Environmental Restoration Branch
OCC	Oklahoma Corporation Commission
ODEQ	Oklahoma Department of Environmental Quality
OpTech	Operational Technologies Corporation
ORBCA	Oklahoma Risk Based Corrective Action
PAH	Polycyclic Aromatic Hydrocarbon
PID	Photo-Ionization Detector
ppm	parts per million
RBCA	Risk Based Corrective Action
RBSL	Risk Based Screening Level
RES	Residual Saturation
Resid	Residential
RETEC	Remediation Technologies, Inc.
RfD	Reference Dose
RPD	Relative Percent Difference
TPH	Total Petroleum Hydrocarbons
TPHCWG	Total Petroleum Hydrocarbon Criteria Working Group
UST	Underground Storage Tank
USZ	Unsaturated Zone
yr	year

TPH CRITERIA WORKING GROUP
FIELD DEMONSTRATION PROJECT:
TINKER AIR FORCE BASE, OKLAHOMA

1.0 INTRODUCTION

A field demonstration of the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) approach was applied at Underground Storage Tank (UST) Site 21, located on the Tinker Air Force Base (AFB), Oklahoma City, Oklahoma. The Working Group approach establishes scientifically defensible Risk Based Screening Levels (RBSLs) for weathered petroleum contaminated sites, using standard site assessment and sampling techniques. It varies, however, in the analytical method for quantifying total petroleum hydrocarbons (TPH) and the risk assessment undertaken to recommended clean-up levels.

Operational Technologies Corporation (OpTech) is contracted by the U.S. Air Force Research Laboratory, Operational Toxicology Branch (AFRL/HEST) to conduct demonstration programs utilizing the Working Group approach for sample analysis and risk assessment. The approach characterizes TPH by hydrocarbon fractions (selected based on partitioning properties) and assesses risks using assigned fraction toxicities. A special chemical analysis is performed which identifies and quantifies each TPH fraction. This approach, when accepted by the regulatory community, can assist government and private industry to focus remediation efforts on sites posing greatest risk to human health and the environment.

1.1 Demonstration Site

Tinker Air Force Base, Oklahoma City, Oklahoma, was selected as one of the demonstration sites for the Working Group approach. Tinker AFB lies in central Oklahoma on the southwest side of Oklahoma City. Tinker AFB was chosen because it is an Air Logistics Center Base, they are closing several UST sites, and the State of Oklahoma currently has a Risk Based Corrective Action (RBCA) based UST closure program and is interested in the Working Group approach for TPH contaminated sites. Additionally, the geology and groundwater characteristics enabled assessment of part of the approach's forecasts.

1.2 Objectives of the Demonstration Project

The major objectives of the demonstration project are:
- Delineation of TPH contamination from existing investigative data and identification of the best locations for gathering a limited number of samples for the demonstration program.
- Assess collection of soil sample protocols and analytical methods at each site for conventional TPH and the Working Group's fractionation analysis.
- Develop correlation between conventional and fractionation analysis results.
- Evaluate the variation in the TPH fractions over the length of the contaminated area and vertically through the soils.
- Assess the impact of holding time on fractionation analytical results.

- Assess concentrations down gradient from the source based upon the fate and transport equations used in the American Society for Testing and Materials (ASTM) RBCA model.
- Develop RBSLs based on hydrocarbon fractions present.
- Comparison of RBSLs based on Working Group approach to those based on the Oklahoma Risk Based Criteria Action (ORBCA).

1.3 Project Execution

The Field Demonstration Project includes identification of States with interest in the approach and demonstration at military bases where investigation of TPH contaminated sites is ongoing. A Phase 1 visit to the Base to meet with site personnel, regional regulators and determine historic site characterization was undertaken in October 1997. As a result of analytical and geotechnical data collected during the Phase 1 visit, a work plan was prepared which included our conceptual site model and sampling strategy. The work plan reflects a Tier 1 assessment effort.

The Phase 1 briefing was attended by Base representatives, Oklahoma Corporation Commission (OCC), Oklahoma Department of Environmental Quality (ODEQ), OpTech and Remediation Technologies, Inc. (RETEC), a subcontractor to OpTech. Site 21, a JP-4 and diesel UST unit, was identified as the prime candidate after review of the data. A work plan that outlined the proposed demonstration project at the Base was developed based on existing data and finalized by April 1998. Sampling was conducted during a Phase 2 visit in May 1998 and analyses completed by Lancaster Laboratories. Lastly, RBSLs were developed and compared against State RBCA levels.

2.0 APPROACH

2.1 Site Selection

Tinker AFB has numerous UST sites in various stages of closure under the OCC Underground Storage Tank Program. Oklahoma has an aggressive program to use RBCA analyses for assessing the risk to human health and the environment from petroleum hydrocarbon contamination. The State currently uses a modified Environmental Protection Agency (EPA) Method 8015 TPH analyses for characterizing TPH contamination at UST sites. ODEQ is interested in applications of the Working Group approach at USTs, refineries, crude oil wellheads and storage tank sites. State interest and the presence of multiple petroleum contaminated sites where application of the Working Group approach may assist in expediting closures were factors in the selection of sites.

2.2 Site Description

Site 21 is located in the northeastern portion of Tinker AFB, southeast of Water Tank 243 and southwest of Building 241. Building 241 is the fire station pump house. It includes the location of the former USTs 286 and 287. Tanks 286 and 287 were both 1,000 gallon steel tanks installed in 1980 and used for storage of JP-4 jet fuel and diesel fuel, respectively. Dispenser pumps associated with these tanks were located directly south of each tank on a raised concrete fueling

island. Both tanks were leak tested annually and passed tightness testing in 1992 and 1993; however, corrosion tests conducted in 1988 indicated that the tanks were not adequately protected. In November 1994, following completion of the Initial Site Characterization Report (Tetra Tech, 1994) and prior to the Investigation for Soil and Groundwater Cleanup, these tanks were removed and replaced. The soils were excavated from an area approximately 15 feet by 18 feet wide by 12 feet deep and were disposed. The tanks were replaced with vaulted steel tanks with spill and overfill prevention devices. The vaulted replacement tanks were installed to the northeast of the former tank pit, which was lined with 40-mil plastic and backfilled. Tank 286R (replacement) contains JP-4 and supplies the east dispenser, while tank 287R contains diesel fuel and supplies the west dispenser (Tinker AFB, 1995).

In summary, the site is an industrial area with surface groundwater at 4 to 6 feet below surface. The site map is presented in Figure 2.1. Previous investigators have concluded the shallow groundwater flows generally to the west with seasonal variations. The entire impacted area is covered with concrete, which reduces infiltration. The conceptual site model for the plume, presented in Figure 2.2, illustrates the plume migrating generally west and being intercepted by disturbed soil near an existing storm drain. We anticipated transport to be as described by the ASTM RBCA method as adopted by the Working Group with vapor phase transport in the dry soil and bulk transport of dissolved TPH in groundwater.
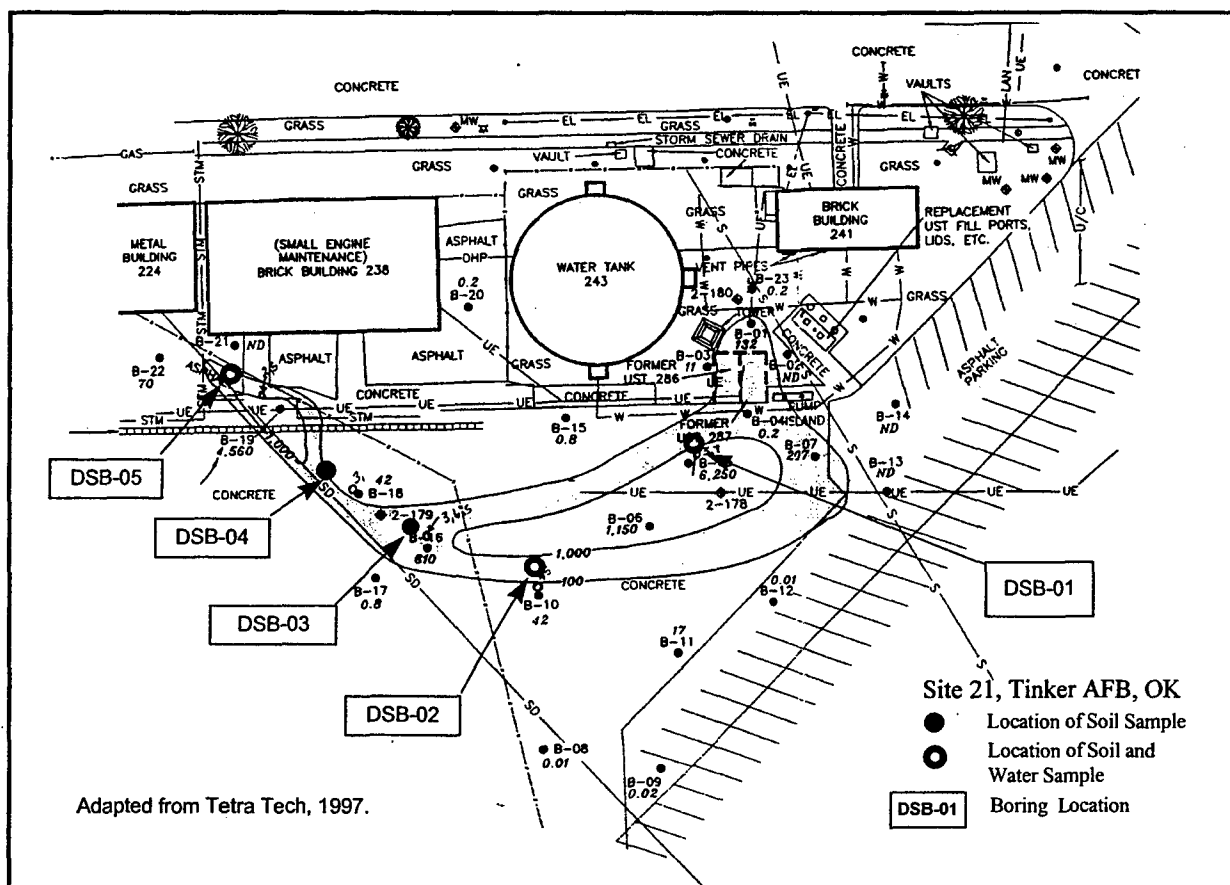
Figure 2.1 Sampling Locations, Site 21, Tinker AFB

3

Rain Infiltration

Soil Surface

Vapor Phase
Diffusion

Water Table

Bulk Transport

Direction of
Groundwater Flow

Water Saturated Phase
Diffusion

Mobile Product Capillary
Diffusion
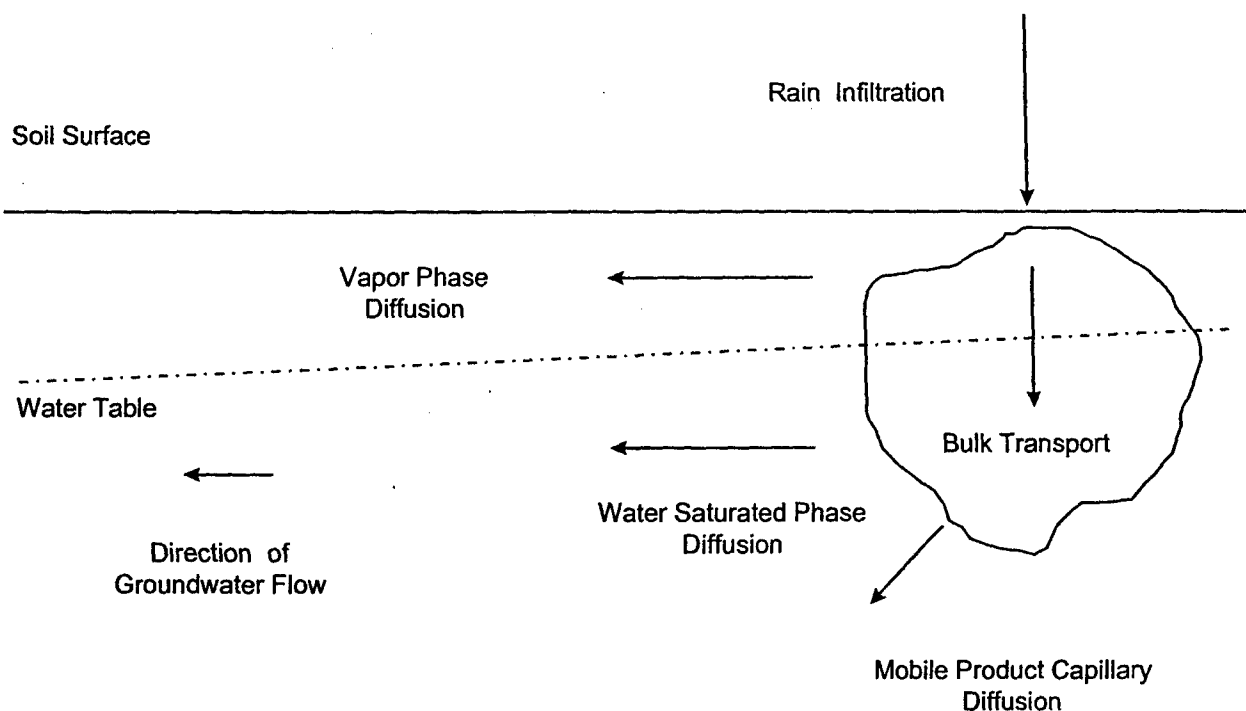
Figure 2.2 Conceptual Site Model

2.2.1 Previous Investigations

In 1994, Tetra Tech performed an Initial Site Characterization which consisted of four soil borings at Site 21 (Tetra Tech, 1994). Soils from this investigation were tested for TPH and benzene, toluene, ethylbenzene and xylenes (BTEX). The TPH concentrations found in the samples ranged from 142 mg/kg in soil boring B-1 to non-detectable in soil boring B-2. BTEX concentrations were found in all four wells: benzene in B-4 was 0.0056 mg/kg; toluene in B-3 was 0.101 mg/kg; ethylbenzene was detected at 0.0971 mg/kg in B-3 and 0.0011 mg/kg in B-4; and xylenes were detected in all four wells in concentrations ranging from 0.0019 to 0.282 mg/kg (Tetra Tech, 1994).

The nature and extent of residual soil contamination at Site 21 was delineated in the Investigation for Soil and Groundwater Cleanup (ISGC) Report (Tetra Tech, 1997). Nineteen borings were drilled and soil samples were analyzed for TPH and BTEX compounds. None of the samples exceeded Oklahoma Corporation Commission Category II cleanup levels for BTEX (5\400\150\1000 mg/kg for benzene, toluene, ethylbenzene, and xylene, respectively) but 6 samples from 5 borings, ranging from 2,054 to 15,042 mg/kg, exceeded the OCC cleanup levels for TPH (500 mg/kg). The highest total combined petroleum hydrocarbons concentration (15,042 mg/kg) was from soil boring BW21-B18-3 at 3.0 to 3.5 feet BGS. The highest purgeable TPH (gasoline) was at 6,250 mg/kg from sample BW21-B5-2.7 (2.7 to 3.5 feet BGS). The soil contamination ranged between 1 and 5.5 feet BGS consistently across the site. Laterally, the plume extends to the west of the original tank pit, but not beyond the underground storm drain, located approximately 175 feet west of the tank area. At the storm drain, the plume abruptly turns to the northwest, following the storm drain excavation. The contamination appears to have followed the direction of the groundwater flow, migrating along the top of the shallow water table.

None of the groundwater samples collected at Site 21 exceeded OCC Category II cleanup levels for BTEX (0.05\10\7\1000 mg/L) or TPH (10 mg/L). The monitoring wells were screened from 3.5 to 13.5 feet BGS, which includes the zone of soil contamination that exceeds OCC cleanup levels. The direction of the groundwater flow is towards the west/southwest and the wells were placed both up and down gradient of the suspected source area as well as within the contaminant plume. Contamination does not appear to have migrated off site and is not expected to impact off site water wells closest to the site, which are approximately 3,200 feet northwest of Site 21.

The recommendation at the time of ISGC completion was that the groundwater did not require further action under OCC regulations; however, a remediation plan for the soil that exceed OCC cleanup levels for TPH was needed, requiring a risk assessment in accordance with OCC Guidance for risk-based corrective action. A Tier 1A ORBCA Report was completed in March 1997; it recommended closure with no further action for the site. A decision on closure by the Oklahoma Corporation Commission is still pending.

2.2.2 Environmental Setting

2.2.2.1 Meteorology

The climate at Tinker AFB is characterized by long, hot summers (occasional droughts of varying duration occur) and comparatively mild winters. During the summer months, the average daily temperatures range from approximately 66 to 94°F. During the winter months, by comparison, the average daily temperatures range from approximately 26 to 54°F. The maximum precipitation generally occurs in May; the average annual precipitation for the region is 33.4 inches. The average evaporation rate is approximately 50 inches. The prevailing wind direction is southerly, but northerly and southerly winds occur with nearly equal frequency from December to March. Average monthly wind speed varies from 12 to 16 miles per hour. Severe wind storms occurring with thunderstorms and low-pressure systems are more frequent in the spring, but can occur during any month (Tetra Tech, 1994).

2.2.2.2 Geology

Bedrock underlying Tinker AFB is composed of sedimentary strata. The geological units that outcrop on the Base are the Permian Age Hennessey Group, the Garber sandstone and the Wellington Formation. The bedrock formations dip to the southwest at approximately 40 to 50 ft per mile. Site 21 lies on the recharge zone of the Garber-Wellington Formation. Outcrops of the Garber sandstone in the northeast portion of Tinker AFB consist of irregularly stacked, fine-grained sands interbedded with silt and clay layers up to four feet thick. The Garber sandstone was deposited in a fluvial-deltaic environment. North of the Base, the Garber sandstone is characterized by small to medium channels with cross-bedded sandstones featuring cut and fill structures (Tetra Tech, 1997).

The Wellington formation has lithology similar to the Garber sandstone, consisting of lenticular beds of fine-grained, cross-bedded sandstone interbedded with siltstone and mudstone. Because lithologies are similar and because of a lack of key beds, the Garber sandstone and the Wellington Formation are difficult to distinguish and are often informally lumped together as the

Garber-Wellington Formation. Together, they are about 900 feet thick at Tinker AFB (Tetra Tech, 1997).

2.2.2.3 Soils

The surface soils of Tinker AFB are predominantly residual or alluvial. The soils in the area of Site 21 are classified as urban land. Filling and grading activities over the years have disturbed or obliterated the natural soils. Site 21 falls within the area mapped by the Soil Conservation Service as having soils of the Renfrow-Vernon-Bethany Association. This association consists of deep and shallow loamy and clayey upland soils that are generally flat to slightly sloping. The Renfrow soils typically have an 8 to 12 inch thick reddish-brown to dark brown clay loam surface layer overlying a 20 to 35 inch clay subsoil. Fine-textured sediments from clay and shale underlie the subsoil. The Vernon soils are similar, but tend to be thinner and are calcareous. The Bethany soils have a surface layer that is dark grayish-brown to dark brown, which is 11 to 18 inches thick. The subsoil is brown or dark grayish-brown and is ≥30 inches thick. This grades to a firm, calcareous, loamy material (USDA/SCS, 1969).

The soil lithology at Site 21 consists of moist, reddish-brown silt interlayered with light gray, black, dark brown and white silts from near the surface to a depth of about three feet below ground level, which grades into beds of reddish-brown silty sand (Tetra Tech, 1994). The sandstone is easily broken up when crushed, but the size and nature of the sandstone resulted in the inability to drive a split spoon sampler into the formation.

2.2.2.4 Hydrogeology

The most important source of potable groundwater in the Oklahoma City metropolitan area is the Central Oklahoma aquifer system. This aquifer extends under much of central Oklahoma and includes water in the Garber Sandstone and Wellington Formation, the overlying alluvium and terrace deposits, and the underlying Chase, Council Grove and Admire Groups. The Garber-Wellington Formation portion of the central Oklahoma aquifer system is commonly referred to as the "Garber-Wellington Aquifer" and is considered to be a single aquifer because these units cannot be easily differentiated and because many of the best producing wells are completed in this zone.

Based on the location of Site 21, the groundwater beneath this site is part of the Unsaturated Zone (USZ) of the Garber-Wellington aquifer system. Groundwater flow in the USZ in the vicinity of Site 21 appears to be to the west; however, the direction of flow may be influenced by seasonal variations that could result in flow to a different direction (Tetra Tech, 1994). At present, Tinker derives most of its water supply from this aquifer and supplements the supply by purchasing from the Oklahoma City Water Department. The nearby communities of Midwest City and Del City derive water supplies from surface sources, but have wells tapping the aquifer for use in the event of an emergency. Industrial operations, individual homes, farm irrigation and small communities not served by a municipal system also depend on the aquifer.

2.2.2.5 Surface Water Drainage Routes for the Base

The ground surface at Tinker AFB varies in elevation from approximately 1,320 feet above mean sea level (MSL) in the southeastern portion of the Base to 1,190 feet MSL in the northwestern portion of the Base. Drainage on Tinker AFB land area is accomplished by overland flow of runoff to diversion structures which empty into area surface streams.

At Site 21, the elevation is approximately 1,252 feet MSL and the surrounding area has been graded or filled to a generally flat surface and covered with concrete. Drainage at the site is to storm drains that empty westward into Kuhlman Creek. The site lies at the boundary of the Kuhlman Creek and Soldier Creek Tributary 2 Watershed, so the northeast portion of the site may drain toward the northeast. Soldier Creek, which would be intermittent under normal conditions, receives continuous discharge from the Base Industrial Water Treatment Plant, cooling towers, etc. Soldier Creek flows into Crutcho Creek which discharges into the North Canadian River, located approximately six miles north of Tinker AFB (Tetra Tech, 1994).

2.3 Sample Collection

Table 2.1 presents the locations and rationale for samples collected at Tinker AFB Site 21. The original sampling strategy (OpTech, 1998) was modified slightly to comply with field situations. Borings for the samples were conducted by Layne, Incorporated, Wichita, Kansas, and Tetra Tech NUS, Inc., Oklahoma City, Oklahoma, provided drilling supervision. Drilling was provided as a government furnished service through the Tinker AFB Environmental Management, Restoration Branch (OC-ALC/EMR) as a joint effort.

Prior investigations were used to develop a site conceptual model relating contaminant transport (Figure 2.2) and to establish a sampling strategy. The model assumed that no free product was present. The sampling strategy was designed to assess vertical dispersion in soil, to determine leaching to groundwater and to compare conventional and Working Group analytical approaches.

TABLE 2.1 SAMPLING PLAN

Boring #	Sample Depth (ft)	Media Sampled	Sample #	Lab #	Sample Method	PID (ppm)	Rationale
DSB01	2-3.5	Soil	4	2926582	Core	>2500	Estimate Source
	6-7	Soil	5	2926583	Core	44	Vertical Dispersion
	N/A	Water	02W	2927363	Bail		Water Transport
DSB02	1-1.75	Soil	1	2926578	Split Spoon	480	Horizontal transport
	4-4.75	Soil	2	2926579	Split Spoon	33	Vertical Dispersion
	10-10.75	Soil	3	2926580	Split Spoon	8`	Vertical Dispersion
	N/A	Water	01W	2926581	Bail	N/A	Water Transport
DSB03	2.5-4	Soil	9	2926584	Core	>2500	Horizontal Transport
	6-7.5	Soil	10	2926585	Core	44	Vertical Dispersion
DSB04	3.5-5	Soil	6	2927360	Core	544	Horizontal Transport
	3.5-5	Soil	11	2927361	Core	544	Quality Control Check
	3.5-5	Soil	6R	2953170	Core	544	Holding Time -30 Days
	3.5-5	Soil	11R	2953171	Core	544	Holding Time -30 Days
DSB05	2-3	Soil	7	2927358	Core	>2500	Horizontal Transport
	8-9	Soil	8	2927359	Core	864	Vertical Dispersion
	N/A	Water	03W	2927362	Bail	N/A	Water Transport

2.3.1 Soil Samples

Samples were collected in accordance with the Field Investigation Work Plan, Total Petroleum Hydrocarbon Criteria Working Group Demonstration Program: Tinker Air Force Base, Oklahoma City, Oklahoma (OpTech, 1998). Figure 2.1 shows the locations of the soil borings.

The nature of the subsurface soils at the site required a change in the sampling method, from split spoon sampling to continuous coring. The very fine-grained sands pulverized and compacted beneath the split spoon sampler requiring greater than 100 blows to drive the split spoon only a few inches. As a result, sample quantity recovered was sometimes less than optimal for analyses. Hence, continuous coring was used during the subsequent borings and sample quantity increased to acceptable levels. A slightly silty clay layer was encountered in soil boring DSB-02 from 10.75 feet below ground surface to 11.75 feet. The clay was blue-gray with some reddish brown mottling and carbonaceous inclusions. This clay was hard and did not break up easily when compositing samples.

Continuous coring can sometimes cause heating of the core barrel and subsequent heating of the samples. This was observed in one of the sample intervals collected through continuous coring, DSB-05 from 8 to 9 feet BGS (Sample # 8). The core barrel was hot to the touch and the soil sample was steaming when the core barrel was opened. This heating of the sample most likely volatilized the light hydrocarbon fraction and caused the Photo-Ionization Detector (PID) readings to be elevated. This sample was marked as "sample steaming" on the chain of custody forms to identify potential concerns about the sample. The PID reading was 864 ppm

when the sample was collected from the core barrel. However, analytical results for this sample returned non-detectable levels for all hydrocarbon fractions. This indicates that heating of the sample may have volatilized the lighter hydrocarbon fraction in the soils in and above the sample point which saturated the whole core interval and gave anomolously high volatile readings for the interval, which led to questionable field screening.

Soil samples were collected from sampling intervals identified in the work plan as points of contamination based on existing site data. The split spoon sampling device could collect a two foot long intact sample while the continuous core device could collect a maximum of a five foot core. Sampling points for the continuous coring device were identified based on core recovery and PID field gas screening. Samples were described by an on-site geologist and recorded on soil boring logs (see Appendix A).

Following field screening, samples were removed from the split spoon or coring device, quickly composited in a stainless steel bowl, put into glass bottles, sealed with security tape and stored on ice. The stainless steel bowl and spoon were washed with Aquanox and water, rinsed and dried between uses. The ice chests were sealed with Chain of Custody seals and shipped overnight to Lancaster Laboratories for analyses. Upon completion of sampling, boreholes were backfilled with cement and bentonite.

2.3.2 Water Samples

Figure 2.1 illustrates the locations of the water samples collected. Shallow groundwater at Site 21 was encountered at 4.05 feet (123.4 cm) BGS during drilling activities. This level was higher than that reported in the Oklahoma Risk-Based Corrective Action Tier 1 and Tier 1-A Report (Tetra Tech, 1997), but is within normal seasonal fluctuations.

Water samples were collected from the open borings with no screen or casing installed. The friability of the soils led to sloughing of soils in the boring. The soils on the sides of the borings continued to cave into the boring causing a high sediment load in the groundwater. The augers were removed and the boring holes were bailed to remove excess sediments from the drilling. The borings were allowed to recharge 2 to 16 hours before sampling. Water samples were collected using a disposable bailer.

The DSB-02 water sample, collected after a two hour recharge, was very muddy and did not readily settle out. DSB-01 was capped to prevent outside contamination and allowed to recharge overnight. The next morning the water level in DSB-01 was at 4.05 feet BGS. Upon opening the cap, the air in the boring had a strong petroleum odor. The groundwater was slightly muddy when bailed but the sediments settled out quickly. The amount of sediment in the water samples covered the bottom of the sample bottles. A water sample from DSB-05 was collected after a four hour recharge. The groundwater was slightly muddy when bailed, but the sediments settled out quickly. The amount of sediment in the water samples covered the bottom of the 125 ml sample bottle.

Water samples were preserved with laboratory provided hydrochloric acid. The water samples were immediately packed in the ice coolers and shipped the same day via overnight express to Lancaster Laboratories for analyses.

2.4 Analytical Approach

Samples were analyzed using a conventional TPH analysis (the Oklahoma modified U.S. EPA Method SW 846-8015A, *Nonhalogenated Volatile Organics by Gas Chromatography/Flame Ionization Detector*, with purge and trap sample preparation), USEPA Method 5030 and the Direct Method for hydrocarbon fractionation. The Direct Method, originally developed by Shell Development Company, separates hydrocarbons into different carbon ranges using gas chromatography (GC). The hydrocarbons are then fractionated into aliphatic and aromatic hydrocarbons using column chromatography. This combination of the column chromatography and gas chromatography is called hydrocarbon speciation (TPHCWG, 1998a).

Following separation of the aromatics and aliphatics on the alumina or silica gel column, the two separate extracts are analyzed by GC/flame ionization detector. The volatiles range analysis can report the BTEX "fractions" or components. Output from the analyses will be reported as aliphatic and aromatic fractions of the petroleum hydrocarbons present in the sample. The hydrocarbon speciation is a tool to determine the non-carcinogenic risk presented by hydrocarbons in a soil or water sample in addition to the risk posed by any of the target compounds in these standard EPA methods.

2.5 Analyses of Results

2.5.1 Quality Assurance

Data from the soil and water samples were analyzed for accuracy. Data accuracy involved the collection of a duplicate sample from DSB-04. The sample was analyzed by the same methods as the other samples. Relative percent differences between the TPH fractions for the duplicates samples are presented in Section 3.2.1. Quality assurance included the analyses of temperature blanks, trip blanks and matrix spiked duplicates.

2.5.2 Correlation of the Direct Method to Conventional TPH Analyses

Data from the Direct Method and Oklahoma modified EPA Method 8015 analyses were collected from the same composite sample intervals on specific soil borings (see Table 2.1). The results were reported as extractable total petroleum hydrocarbons and purgable total petroleum hydrocarbons from the Direct Method, and as gasoline range organics (GRO) and diesel range organics (DRO) from Method 8015M. These data were analyzed using standard regression analysis through a spreadsheet application.

2.5.3 Characterization of Variability of Fractions with Lateral and Vertical Dispersion

Another objective of this demonstration project was the study of variability in petroleum fractions over the length and depth of the contaminated soils and groundwater. Variability in the fractions at particular points in the zone of contamination is important in the verification of the conceptual model. If the conceptual model is verified, it is possible to estimate the fraction concentrations down gradient from the source and to optimize the number of samples required for the Direct Method analyses.

Variations in the fraction profiles occur due to differences in the mobility of the fractions. Mobility of the fractions affects dispersion and diffusion. Hence, a change in fraction concentrations may occur both down gradient of the source and perpendicular to the groundwater flow.

Samples were collected at varying distances along the centerline of the contaminant area based on data collected during previous investigations. Demonstration soil boring DSB-02 was drilled at the edge of the contaminant area to investigate changes in the hydrocarbon fractions due to lateral diffusion. Samples were collected at different depths within those soil borings to evaluate vertical variability of the hydrocarbon fractions. However, evaluation of vertical variability was limited due to the presence of shallow groundwater.

2.5.4 Analysis of the Impact of Holding Time on Sample Results

The length of time a sample is held prior to analysis can often be an issue. Exceeding the holding time can compromise data leading to installation of additional soil borings and resampling. In order to analyze the impact of holding time on sample results, 2 duplicate samples were held longer than the recommended holding time of 15 days from collection. These samples were analyzed using the Direct Method 30 days after collection. Relative Percent Differences (RPDs) and linear regressions were calculated on the TPH fractions resulting from the initial analyses and the analyses after exceeding the holding time.

2.5.5 Analysis of Fate and Transport Prediction

The basis of the ASTM RBCA calculated screening levels is the fate and transport of the contaminants. Using the conceptual model based on partitioning and transport of the contaminants, one should be able to predict concentrations in the soils, groundwater and vadose zone vapors. These predicted concentrations should be comparable to the analytical results if the model is valid in this situation. Therefore, one of the objectives of this demonstration project is to assess calculated concentrations in the soils and groundwater down gradient of the source.

Data from the Direct Method analyses and the geotechnical data were applied to fate and transport equations from ASTM Standard E1739 (1995) and TPHCWG Approach (1998b). The TPHCWG Approach provides some of the transport equations from the RBCA process and physical characteristics for the hydrocarbon fractions.

Estimated leachate factors to groundwater from contaminated soils were calculated based on the RBCA equations. In order to check for potential free product, the saturated concentrations for the soils were calculated using the models in the RBCA process. These predicted concentrations were compared to results from the Direct Method analyses.

The leaching factor is characterized as the ratio between the chemical concentration in groundwater to the chemical concentration in the subsurface soils (TPHCWG, 1998b). The leaching factor multiplied by the soil concentration should estimate the concentration in the

groundwater. Leaching of the hydrocarbon fractions to groundwater is estimated by the equation:

$$LF = \frac{\rho_s}{[\theta_{ws} + k_s + H_c\theta_{as}]\left(1 + \frac{U_{gw}\delta_{gw}}{IW}\right)}$$

where:

LF	=	Leaching factor [mg/L H_2O/mg/kg soil]
ρ_s	=	Soil density [g/cm^3]
θ_{ws}	=	Soil volumetric water content [cm^3/cm^3]
k_s	=	Soil sorption coefficient (K_{oc}*f_{oc}) [cm^3/g]
H_c	=	Henry's Law Constant [atm-m^3/mol]
θ_{as}	=	Soil volumetric air content [cm^3/cm^3]
U_{gw}	=	Groundwater Darcy velocity [cm/yr]
δ_{gw}	=	Groundwater mixing zone thickness [cm]
I	=	Infiltration rate of water through soil [cm/yr]
W	=	Width of source area parallel to groundwater flow direction [cm]

2.6 Tier 1 Risk Assessment Approach

The first step in the Tier 1 assessment was the identification of contaminant sources, transport mechanisms, exposure pathways and potential receptors based on existing site information. Carcinogenic indicators (benzene and polycyclic aromatic hydrocarbons (PAHs)) were not detected in the soil sampled for this effort. Therefore, for purposes of establishing soil cleanup criteria, only noncarcinogenic risk was calculated. RBSLs were then calculated for each exposure pathway by applying the TPH fractionation results and the procedures established by the Working Group. The approach used for calculating TPH RBSLs differs from that used in a typical ASTM RBCA (1995) analysis in that it incorporates the concepts of additivity of risks (for the TPH mixture), chemical saturation concentrations (C_{sat}) and residual saturation (RES). Treating TPH as a mixture is especially important for consideration of fate, transport and toxicological interactions between individual chemicals or fractions.

Noncarcinogenic risk for each fraction is represented by the hazard quotient (HQ), which is the ratio of the estimated daily intake of a contaminant in given media (e.g., soil) to a reference dose (RfD) as follows:

$$HQ_i = \frac{Intake\,Rate(^{mg}/_{kg-day})}{RfD_i(^{mg}/_{kg-day})}$$

The intake rate depends upon the frequency and duration of exposure, as well as the source concentration and the transport rates between the source and the receptor for cross media pathways. Additivity is incorporated into the calculation of a "whole TPH" hazard index (HI) and RBSL by apportioning the total risk (i.e., HI = 1 for the mixture) over the different fractions present. That is, rather than each fraction assuming risk equal to a HQ of 1, each fraction would be allotted a portion of the risk, with the sum of the HQs from each fraction less than or equal to the HI of 1 for the mixture as depicted in the equation below.

$$HI = \sum_{i=1}^{i=n} HQ_i = \sum_{i=1}^{i=n} \frac{f_i C_{TPH}}{RBSL_i} \leq 1$$

where:

HI = Hazard Index (typically ≤ 1) [unitless]
n = Number of fractions (13 total)
HQ_i = Hazard Quotient for i^{th} specific fraction [unitless]
f_i = Percent Weight of ith TPH fraction in "whole TPH" mixture [unitless]
RBSL = Tier 1 risk-based screening level for a TPH fraction [mg/kg]
C_{TPH} = TPH concentration in soil [mg/kg]

The assumption of additivity for calculating a mixture RBSL for TPH is highly conservative because the toxicological information for the target fractions indicates that these fractions impact different organs (see Section 2.6.2). Typically, additivity is appropriate for constituents or constituent classes which impact the same organ.

For cross media pathways where transport, and therefore exposure, are maximized at the saturation concentration for specific fractions, the following equation is solved:

$$HI = \sum_{i=1}^{i=n} HQ_i = Min\left(\sum_{i=1}^{i=n} \frac{f_i C_{TPH}}{RBSL_i}, \sum_{i=1}^{i=n} \frac{C_{isat}}{RBSL_i} \right) \leq 1 \quad \text{given,}$$

$$\sum_{i=1}^{i=13} f_i = \sum_{i=1}^{i=n} \frac{C_i}{C_{TPH}} = 1$$

where:

$C_{i\,sat}$ = Saturation concentration for i^{th} TPH fraction [mg/kg]
C_{TPH} = TPH Concentration [mg/kg]

C_{sat} serves as an upper exposure limit for cross media pathways. It represents the chemical concentration in soil at which the sorption limits of the soil particles, the solubility limits of the soil pore water and the saturation limit of the soil pore air have been reached. A concentration above the C_{sat} does not indicate the presence of mobile, free-phase chemicals. Actual mobility of a non-aqueous phase liquid (NAPL) depends on product and soil properties which are characterized by various capillary, gravitational, hydrodynamic and surface tension forces. However, at soil concentrations greater than C_{sat}, the likelihood of free phase NAPL should be considered. Once free product transfers, the assumptions of the Working Group's approach are no longer valid and multi-phase transport should be considered. The calculation for C_{sat} is defined as:

$$C_{sat}\left[\frac{mg}{kg}\right] = \frac{S}{\rho_s} * [H_c \theta_{as} + \theta_{ws} + k_s \rho_s]$$

where:

S = Water Solubility [mg/L]
ρ_s = Soil Bulk Density [g/cm^3]
H_c = Henry's Law Constant [cm^3/cm^3]

θ_{as} = Volumetric air content of the soil [cm^3/cm^3]
θ_{ws} = Volumetric water content of the soil [cm^3/cm^3]
k_s = Soil-water sorption coefficient ($k_s = K_{oc} * f_{oc}$) [cm^3/g]

The C_{sat} limit does not apply to direct exposure pathways, such as the surface soil contact pathway. The exposure is to the original impacted media (e.g., contaminated soil) rather than to the cross media to which the contamination has been transferred.

A similar term which is sometimes confused with C_{sat} is residual saturation. When calculating an RBSL, a value of RES means that the selected risk level (e.g., HI = 1) could not be reached or exceeded for the pathway and scenario given the constituents present, regardless of the contaminant concentration. A value of RES is obtained at the TPH concentration where the C_{sat} of the mixture is reached (i.e., each fraction has reached C_{sat}). When calculating a "whole TPH" RBSL, this means that even if the concentration of each fraction is set equal to C_{sat} for that fraction and pathway, the combined risk associated with each fraction still does not equal a HI of "1".

2.6.1 Physical Properties of the TPH Fractions

The 13 fractions in the Working Group approach were selected based on order of magnitude differences in partitioning properties. These properties are used in simple fate and transport models to evaluate the partitioning and migration of the TPH fractions for the different applicable pathways. This allows a more accurate estimation of exposure to the complex mixture than can be modeled from single TPH measurements.

Chemical properties which specifically govern how a chemical interacts with its environment include solubility, vapor pressure, sorption coefficient and Henry's Law Constant. In general, for any effective carbon (EC) number, the solubility of aromatic hydrocarbons is greater than that of aliphatic hydrocarbons; this is especially noticeable at high EC values. The variability in solubility around any given EC value is about an order of magnitude. Aromatic hydrocarbons are more likely to be present as dissolved constituents in groundwater than are the corresponding aliphatic hydrocarbons. There is very little difference in vapor pressure between aliphatic and aromatic constituents of an equivalent EC. In effect, the EC and vapor pressure are closely related.

The soil-water sorption coefficient (k_s) expresses the tendency of a chemical to be adsorbed onto a soil particle. In general, aliphatic fractions are more likely to remain bound to a soil particle than the aromatic fraction of an equivalent EC. Similarly, they exhibit low solubility.

Henry's Law Constant (H_c) the ratio of a compound's concentration in air to its concentration in water at equilibrium. In general, aliphatic hydrocarbons are less soluble and more volatile than aromatic hydrocarbons. It is important to note, however, that benzene, an aromatic compound, is very volatile and more toxic than the corresponding aliphatic fractions. Therefore, when present, benzene is likely to drive risk calculations for pathways involving volatilization from soil or groundwater.

The physical properties of the 13 TPH fractions used to determine partitioning factors are provided in Table 2.2. The equations used to develop these fate and transport properties are available in the Working Group approach (TPHCWG, 1998b).

TABLE 2.2 TPH FRACTIONS DERIVED FROM FATE AND TRANSPORT CHARACTERISTICS AND ASSOCIATED PROPERTIES (BASED ON AN EQUIVALENT CARBON NUMBER[1])

	Solubility (mg/L)	Henry's Constant	Molecular Weight (g/mol)	Vapor Pressure (atm)	log K_{oc}[2] (cm³/cm³)	PF[3] (soil/water)	PF[3] (soil/vapor)
Aliphatics							
EC5-EC6	3.6E+01	3.4E+01	8.1E+02	3.5E-01	2.9E+00	1E+01	3E-01
>EC6-EC8	5.4E+00	5.1E+01	1.0+02	6.3E-02	3.6E+00	4E+01	9E-01
>EC8-EC10	4.3E-01	8.2E+01	1.3E+02	6.3E-03	4.5E+00	3E+02	6E+00
>EC10-EC12	3.4E-02	1.3E+02	1.6E+02	6.3E-04	5.4E+00	3E+03	5E+01
>EC12-EC16	7.6E-04	5.4E+02	2.0E+02	4.8E-05	6.7+E00	7E+04	1E+03
>EC16-EC35	1.3E-06	6.4E+03	2.7E+02	7.6E-06	9.0E+00	1E+07	1E+05
Aromatics							
EC6-EC7	1.8E+03	2.3E-01	7.8E+01	1.3E-01	1.9E+00	9E-01	4E+00
>EC7-EC8	5.2E+02	2.7E-01	9.2E+01	3.8E-02	2.4E+00	2E+00	9E+00
>EC8-EC10	6.5E+01	4.9E-01	1.2E+02	6.3E-03	3.2E+00	2E+01	5E+01
>EC10-EC12	2.5E+01	1.4E-01	1.3E+02	6.3E-04	3.4E+00	2E+01	2E+02
>EC12-EC16	5.8E+00	5.4E-02	1.5E+02	4.8E-05	3.7E+00	5E+01	2E+03
>EC16-EC21	5.1E-01	1.3E-02	1.9E+02	7.6E-06	4.2E+00	1E+02	4E+04
>EC21-EC35	6.6E-03	6.8E-04	2.4E+02	4.4E-09	5.1E+00	1E+03	3E+07

Notes:
- Table extracted in part from TPHCWG, 1998b.
- [1] Equivalent carbon number (EC) is proportional to normal boiling point .
- [2] K_{oc} = organic carbon sorption coefficient
- [3] PF – partition factors for soil to water and soil to vapor concentrations at equilibrium
- Values based on pure compounds. Behavior may differ in complex mixtures

2.6.2 Overview of Toxicity Criteria for Fate and Transport Fractions

The Working Group approach focuses on both carcinogenic and non-carcinogenic impacts to human health. In order to assess carcinogenic risk, indicator compounds are used (benzene and the carcinogenic PAHs). The assessment of non-carcinogenic risk uses the fraction-specific toxicity criteria summarized in Table 2.3. The majority of constituents in TPH are noncarcinogenic.

RfDs are estimates of daily exposure to the human population, including sensitive subgroups, that are likely to be without appreciable risk of deleterious effects during a lifetime. RfDs are developed for non-carcinogenic compounds. In some cases, the same toxicity criterion is assigned to different fate and transport fractions due to the similarity of toxicity findings across fractions or limitations in the available toxicity data. Yet, the fractions are assessed separately so that the exposure potential of each fraction may be estimated appropriately. Combining fate and transport information with the RfDs for each fraction, fraction-specific RBSLs could be estimated for each applicable exposure scenario. These fraction-specific RBSLs may then be combined with a site-specific mixture composition to calculate a single mixture-specific TPH RBSL.

TABLE 2.3 WORKING GROUP TOXICOLOGY FRACTION-SPECIFIC RfDs
(mg/kg/day)

Effective Carbon Range	Aromatic RfD	Critical Effect	Aliphatic RfD	Critical Effect
EC5–EC6 EC7–EC8	0.20 - Oral 0.10 - Inhalation	Hepatoxicity, Nephrotoxicity	5.0 - Oral 5.0 - Inhalation	Neurotoxicity
EC9–EC10 EC11–EC12 EC13–EC16	0.04 - Oral 0.05 – Inhalation	Decreased body weight	0.1 - Oral 0.3 - Inhalation	Hepatic and hematological changes
EC17–EC21 EC22–EC34	0.03	Decreased body weight	1.00	Hepatic (foreign body reaction) granuloma
>EC34	—	—	20 - Oral	Hepatic changes

If carcinogenic indicators are present, they must be evaluated separately since they often drive cleanup even in relatively low concentrations. The hazard assessment for TPH fractions would only be used in cases where indicator compounds are not present or are present below regulatory action levels. More information on the development of the RfDs is provided in TPHCWG, 1998c.

In general, aromatic fractions have lower RfDs than aliphatic fractions, and are approximately an order of magnitude more toxic than the corresponding aliphatic fraction. These values are based on chronic effects which include hepatoxicity (liver toxicity), nephrotoxicity (kidney toxicity) and decreased body weight.

3.0 RESULTS AND DISCUSSION

3.1 Analytical Results

Analytical results of the TPH fractions are summarized in Table 3.1. Chain of custody forms and the laboratory data sheets are provided in Appendices B and C, respectively. The analytical results provide the basis for interpretation of the characteristics of the contamination and for the risk analyses that provide screening levels for the site.

TABLE 3.1 DIRECT METHOD RESULTS OF SOIL SAMPLES[1,2,3]

Soil Boring Number:	DSB-01	DSB-02	DSB-02	DSB-03	DSB-04	DSB-04	DSB-05
Depth:	2-3.25'	1-1.75'	4-4.75'	2.5-4'	3.5-5'[5]	3.5-5'[5]	2-3'
Laboratory ID:	2926582	2926578	2926579	2926584	2927360	2927361	2927358
Sample ID:	4	1	2	9	6[5]	11[5]	7
5-6 Aliphatics	<44	<0.2	<0.23	<44	<22	<45	<44
5-7 Aromatics (Benzene)	<1	<0.006	<0.006	<1	<0.6	<1	<1
>6-8 Aliphatics	<44	<0.2	0.78	95	<22	<45	<44
>6-8 Aromatics (Toluene)	<1	<0.006	<0.006	3.2	0.942	0.942	<1
>8-10 Aliphatics	1182	13.6	<9	3981	2737.7	1102.5	1299.1
>8-10 Aromatics	130.8	<9	<9	700	321	164.9	152.5
>10-12 Aliphatics	1672	221	76.2	5169	4479.9	2087.1	1119.5
>10-12 Aromatics	319.8	25.4	28.5	1408	950.3	529.8	234.3
>12-16 Aliphatics	<109	<22	<23	258	239	<113	117
>12-16 Aromatics	53	<22	<23	147	92	54	44
>16-21 Aliphatics	<23	23	<23	<222	<112	<112	22
>16-21 Aromatics	42	<22	<23	112	34	34	<22
>21-35 Aliphatics	<273	<56	<57	<554	<280	<282	97
>21-35 Aromatics	<55	<56	<57	<227	<56	<56	<56
Total Aliphatics[4]	3010	307	<114	9760	7548	3376	2697
Total Aromatics[4]	578	<111	<114	2490	1407	778	467
Total Aliphatics + Aromatics[4]	3587	360	150	12250	8956	4154	3163

Notes:
- All units in mg/kg, dry weight.
- Nondetects (NDs) are indicated by a "<" limit of quantitation (LOQ) value.
- Samples 3,5,8 and 10 were nondetects and therefore not presented.
- Totals do not necessarily reflect the arithmetic sum of the detected fraction values because NDs are not necessarily zeros and contribute to the area under the chromatogram curve yielding the total values.
- Samples 6 and 11 are field duplicates.
- Analytical results report aliphatics EC21-35 as presented, the Working Group approach combines this fraction with EC16-21.

Evaporative and biological weathering will have a tendency to remove lighter hydrocarbons (ranges <EC12) and the residual hydrocarbons contamination will be predominantly the heavier hydrocarbons (>EC12 to EC35 ranges). The Direct Method analysis indicates hydrocarbon contamination in most soil borings that is mostly >EC8 to EC12 ranges. There are, however, low levels of >EC12 to EC21 ranges in most of the soil borings. This suggests that very little weathering has occurred. The exception to this is the analyses from DSB-02, with low or non-detectable levels of the >EC8 to EC10 fraction. DSB-02 was drilled to test the variability in hydrocarbon composition on the periphery of the contaminant plume. The fractions present may indicate that the hydrocarbons in this soil boring have undergone greater weathering and biodegradation than hydrocarbons in the middle of the contaminant area.

Groundwater samples were also analyzed using the Direct Method. Table 3.2 shows the results of these analyses. The analyses of the water samples show a similar trend of predominantly >EC8 to EC12 ranges with some >EC12 to EC35 fractions evident. Previous investigations found TPH in the groundwater at levels of 0.032 to 1.356 mg/L. The results from

the Direct Method analyses were three orders of magnitude higher than the highest results from previous investigations. The analyses for the water fraction does not include filtration of the sediment in the water; therefore, the sediment most likely accounts for the results of the water analyses. This is most evident in the higher hydrocarbon fractions that have a very low solubility in water.

TABLE 3.2 DIRECT METHOD RESULTS OF WATER SAMPLES[1,2,3]

Soil Boring Number:	DSB-01	DSB-02	DSB-05
Laboratory ID:	2927363	2926581	2927362
Sample ID:	WS2	WS1	WS3
5-6 Aliphatics	<0.05	0.1	0.2
5-7 Aromatics (Benzene)	0.0191	0.01	0.06
>6-8 Aliphatics	0.1640	<0.05	0.2
>6-8 Aromatics (Toluene)	0.0045	0.006	0.04
>8-10 Aliphatics	229.5	0.05	91.3
>8-10 Aromatics	24.1	0.02	49.8
>10-12 Aliphatics	275.6	0.4	65.6
>10-12 Aromatics	62.8	0.2	65.7
>12-16 Aliphatics	18.3	0.03	9.5
>12-16 Aromatics	8.0	0.03	6.4
>16-21 Aliphatics	4.4	<0.02	3.0
>16-21 Aromatics	2.7	0.08	2.5
>21-35 Aliphatics	19.1	<0.05	11.8
>21-35 Aromatics	4.2	<0.05	5.06
Total Aliphatics[4]	547.2	0.68	181.6
Total Aromatics[4]	101.8	0.36	129.5
Total Aliphatics + Aromatics[4]	648.9	1.04	311.0

Notes:
- All units in mg/L
- NDs are indicated by a "<" LOQ result.
- Samples 3,5,8 and 10 were nondetects and therefore not presented.
- Totals do not necessarily reflect the arithmetic sum of the detected fraction values because NDs are not necessarily zeros and contribute to the area under the chromatogram curve yielding the total values.
- Analytical results report aliphatics EC21-35 as presented, the Working Group approach combines this fraction with EC16-21.

3.1.1 Comparison of Data Accuracy

Data accuracy was analyzed by comparison of soil sample duplicates. A sample from DSB-04, 3.5 to 5 feet BGS, was collected and submitted for analysis as two different samples: "Sample 6- DSB-04, 3.5 to 5 feet"; and "Sample 11- DSB-04, 5 to 6.5 feet". The duplicate samples were labeled with different sample depths in accordance with the OpTech quality assurance plan (1992). The analytical results were compared and the data presented in Table 3.3.

TABLE 3.3 COMPARISON OF DATA ACCURACY IN SOILS

Effective Carbon Number Range	Sample 6 - DSB-4 (mg/kg)	Sample 11 - DSB-4 Duplicate (mg/kg)	Quantitative Average	RPD (%)
5-6 Aliphatics	ND	ND	0	NA
5-7 Aromatics (Benzene)	ND	ND	0	NA
>6-8 Aliphatics	ND	ND	0	NA
>6-8 Aromatics (Toluene)	0.942	ND	0.471	NA
>8-10 Aliphatics	2738	1103	1920	85
>8-10 Aromatics	321	165	243	64
>10-12 Aliphatics	4480	2087	3284	73
>10-12 Aromatics	950	530	740	57
>12-16 Aliphatics	239	ND	120	NA
>12-16 Aromatics	92	54	73	52
>16-21 Aliphatics	ND	ND	0	NA
>16-21 Aromatics	34	23	29	39
>21-35 Aliphatics	ND	ND	0	NA
>21-35 Aromatics	ND	ND	0	NA
Total Aliphatics	**7,457**	**3,190**	**5,324**	**80**
Total Aromatics	**1,398**	**772**	**1,085**	**58**
Total Hydrocarbons	**8855**	**3962**	**6,409**	

Notes:
- ND = Nondetects.
- NA = Not applicable, a RPD between reported quantities and non-detectable quantities of any fraction is not applicable.
- RPD = Relative percent difference.
- Totals do not necessarily reflect the arithmetic sum of the detected fraction values because NDs are not necessarily zeros and contribute to the area under the chromatogram curve yielding the total values.
- Analytical results report aliphatics EC21-35 as presented, the Working Group approach combines this fraction with EC16-21.

Relative percent differences were calculated based on 44 FR 69533 (Federal Register, 1979). RPD is calculated using the following equation:

$$RPD = [(X_1 - X_2)/X_{AVG}] * 100$$

where:
RPD   =   Relative Percent Difference [unitless]
X_1 =   Analyte concentration of first duplicate [mg/kg]
X_2 =   Analyte concentration of second duplicate [mg/kg]
X_{AVG} =   Average analyte concentration of duplicates one and two [mg/kg]

RPDs ranged from 39% to 85% difference for those hydrocarbon fractions that returned at least one value from the two duplicate samples. The average difference for all the RPDs for these two samples is 61.63%. Table 3.3 shows that the analyses from DSB-06 resulted in quantities of ranges >EC6 to EC8 and aliphatic ranges >EC12 to EC16, where the duplicate (Sample 11)

had non-detectable levels of these ranges. A RPD between reported quantities and non-detectable quantities of any fraction is not applicable, as it always exceeds 200%.

3.1.2 Comparison of Field Screening Readings to Direct Method

Table 3.4 shows the field PID readings relative to results from the Direct Method and EPA Method 8015M (GRO and DRO analyses) analytical results. These data indicate field-screening readings relate well to analytical results, but that PID readings of at least 200 ppm may be required to identify soil contamination levels that will provide usable data from the Direct Method. Although the PID reading from DSB-02, 4 to 4.75 feet, was 33.4 ppm and the Direct Method results show approximately 150 ppm hydrocarbons, the majority of the PID readings less than 480 ppm resulted in non-detectable levels of hydrocarbons through analyses by the Direct Method. The lower PID reading from DSB-02 indicates a degree of weathering, which has eliminated the volatile fractions from the soils. The PID reading from DSB-05, 8 to 9 feet, is the exception; this reading is anomalous due to heating of the sample from continuous coring. In summary, TPH concentrations and PID readings correlate well at sites with little or no weathering. At well weathered sites, PID readings may not be indicative of TPH levels, however it still provides a useful tool for screening hot spots.

TABLE 3.4 COMPARISON OF EPA 8015M AND DIRECT METHODS IN SOILS

Boring Number	Depth (ft BGS)	PID Reading (ppm)	TPH-Ext (mg/kg)	TPH-Purge (mg/kg)	"Whole TPH" from Direct Method	GRO (mg/kg)	DRO (mg/kg)	GRO + DRO (mg/kg)	RPD (%) 8015M vs Direct Method
DSB-01	2-3.25	>2500	3,559	29	3,588	4,400	2,500	6,900	63.9
DSB-01	6-7	44	ND	ND	0	84	40	124	NA
DSB-04	3.5-5	544	8,932	24	8,956	7,000	3,700	10,700	18.0
DSB-05	2-3	>2500	3,120	43	3,163	3,700	1,600	5,300	51.8
DSB-05	8-9	864	ND	ND	0	30	11	41	NA

Notes:
- TPH-Ext = Extractable hydrocarbons from Direct Method
- TPH-Purge = Purgable hydrocarbons from Direct Method (EC5 to EC8)
- >2500 = PID reading reached maximum value
- NA = Not Applicable – a RPD between reported quantities and non-detectable quantities of any fraction is not applicable.
- ND = Nondetect
- Dup = Duplicate sample run for quality control

3.1.3 Comparison of Direct Method and Conventional Analyses

One objective of the demonstration project is to compare results of sample analyses using the conventional TPH and Direct Methods. Conventional analyses comprising Oklahoma modified EPA Method 8015 and BTEX USEPA Method 8020 were run on selected samples for comparison with the Direct Method. The results of the analyses are presented in Table 3.5, which shows that soils with higher levels of hydrocarbon contamination have differences ranging from 18% to 64% with an average difference of 44.6%. Soils with contamination levels

less than 200 ppm hydrocarbons typically have non-detectable levels of the hydrocarbon fractions when analyzed by the Direct Method.

TABLE 3.5 COMPARISON OF SOIL RESULTS FROM PREVIOUS INVESTIGATIONS WITH RESULTS FROM DEMONSTRATION PROJECT

Boring Number	Depth (ft BGS)	TPH-Extractable (mg/kg)	GRO (mg/kg)	DRO (mg/kg)	Benzene (µg/kg)	Toluene (µg/kg)	Ethyl-benzene (µg/kg)	Xylenes (µg/kg)
DSB-01	2-3.25	3,559	4,400	2,500	<1,000	2,900	4,900	<30,000
BW21-B05	2.7-3.5		6,250	6,790	ND	ND	ND	8,200
DSB-01	6-7	ND	84	40	<40	<40	99	<600
BW21-B05	7.2-7.5		26	137	ND	ND	ND	ND
DSB-02	1-1.75	360	NA	NA	ND	<5	33	<150
BW21-B10	1-1.5		41.8	17	ND	ND	ND	72.6
DSB-02	4-4.75	149	NA	NA	ND	<5	82	<150
DSB-02	10-10.75	ND	<1	ND	<10	<10	ND	<30
DSB-03	2.5-4	12,141	NA	NA	<500	2,600	13,000	95,000
BW21-B16	3-3.5		610	9,680	ND	1,130	1,040	20,300
DSB-03	6-7.5	ND	NA	NA	ND	<5	ND	ND
DSB-04	3.5-5		7,000	3,700	<200	720	4,500	<30,000
DSB-04 Dup	3.5-5		NA	NA	<2,000	<2,000	3,300	12,000
BW21-B18	3-3.5		42.3	15,000	1,200	1,620	6,820	60,500
DSB-05	2-3	3,120	3,700	1,600	ND	<2,000	4,100	<30,000
BW21-B19	2-2.5		3,620	2,710	ND	2,060	5,520	36,500
DSB-05	8-9	ND	30	11	<40	<40	<40	<240

Notes:
- Samples from "BW21-" borings are from previous investigations by Tetra Tech (1997)
- TPH-Extractable from Direct Method
- <1000 = Value is less than the LOQ
- NA = Not Available – Analyses not run
- Dup = Duplicate sample run for quality control

The results from the Direct and conventional methods were analyzed using standard regression analysis. A correlation coefficient (R^2) of 0.9133 was reported (see Figure 3.1). This represents a good correlation between the Direct Method and conventional TPH analyses.
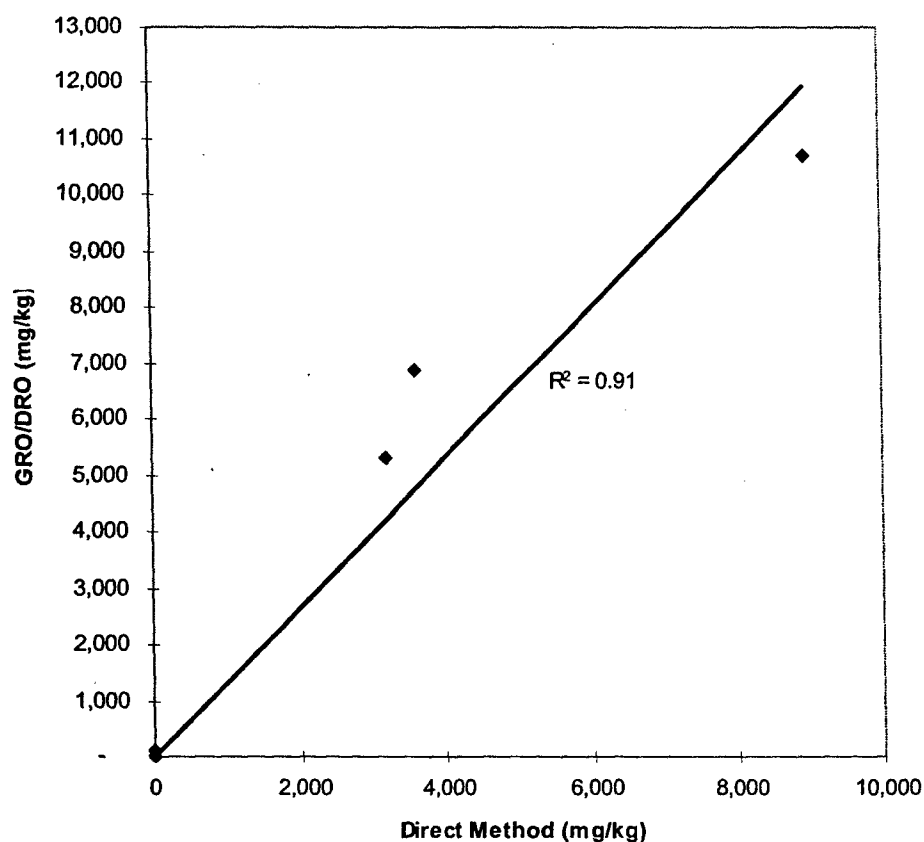
Figure 3.1 Correlation Between Conventional TPH and Direct Method Results

Data from previous investigations were compared to the data results from the demonstration project. Table 3.5 shows the data from soil borings from previous investigations that are within three to four feet of those installed for the demonstration project. These data tend to agree well, allowing for variations in laboratories, distance between samples and depth of samples. Table 3.5 also shows that the relationship between GRO and DRO can change with depth and location of the soil sample. Several samples from the demonstration project had higher amounts of gasoline range than diesel range organics. These data are consistent with the fractionation data from the Direct Method analyses. Generally greater diesel range organics were reported in previous investigations. This may be a variation in laboratory analyses, but most likely includes natural fractionation that occurs with depth. The high water level at the site may account for increased gasoline range organics from 3.5 to 4 feet BGS. When the water level is higher than normal, it can mobilize lighter organics, causing them to migrate vertically while heavier organics remain adhered to soils below the water level. Analyses for BTEX were also included in the demonstration. Table 3.5 includes BTEX for the previously installed and demonstration project soil borings. These data also agree fairly well.

The values from the Direct Method are comparable to conventional TPH analyses using the Oklahoma modified EPA Method 8015A. A good correlation between the two methods results would allow investigators to delineate the extent of contamination with the cheaper conventional method while applying RBSLs based on a few samples analyzed by the Direct Method.

22

3.2 Lateral and Vertical Variability of TPH Contamination

Variations in hydrocarbon fractions may occur down gradient from the source, due to differences in the mobility of the fractions. The 13 fractions used by the Working Group were chosen partially upon the differences in mobility of the fractions.

To analyze variability in the hydrocarbon fractions, relative percentages of the fractions were calculated and graphed. Figure 3.2 maps the percent "whole TPH" of the aliphatic and aromatic fractions. The relative percentages of aliphatic and aromatic fractions are approximately the same throughout the centerline of the contamination. The relative percentages of the two fraction types change along the edge of the contaminated area at DSB-02. Figure 3.3 is a chart that exhibits the changes in hydrocarbon fractions by soil boring and depth. This figure shows that the contaminants are predominantly >EC10 to EC12 range, but the percentage of >EC8 to EC10 range increases with distance down gradient of the source of contamination. DSB-05, the soil boring farthest down gradient of those drilled for the demonstration project, exhibits a greater percentage of effective carbon range >EC8 to EC10 than >EC10 to EC12. These changes in the hydrocarbon fractions are expected based on relative differences in mobility of the fractions and weathering at the upgradient end of the contamination plume.
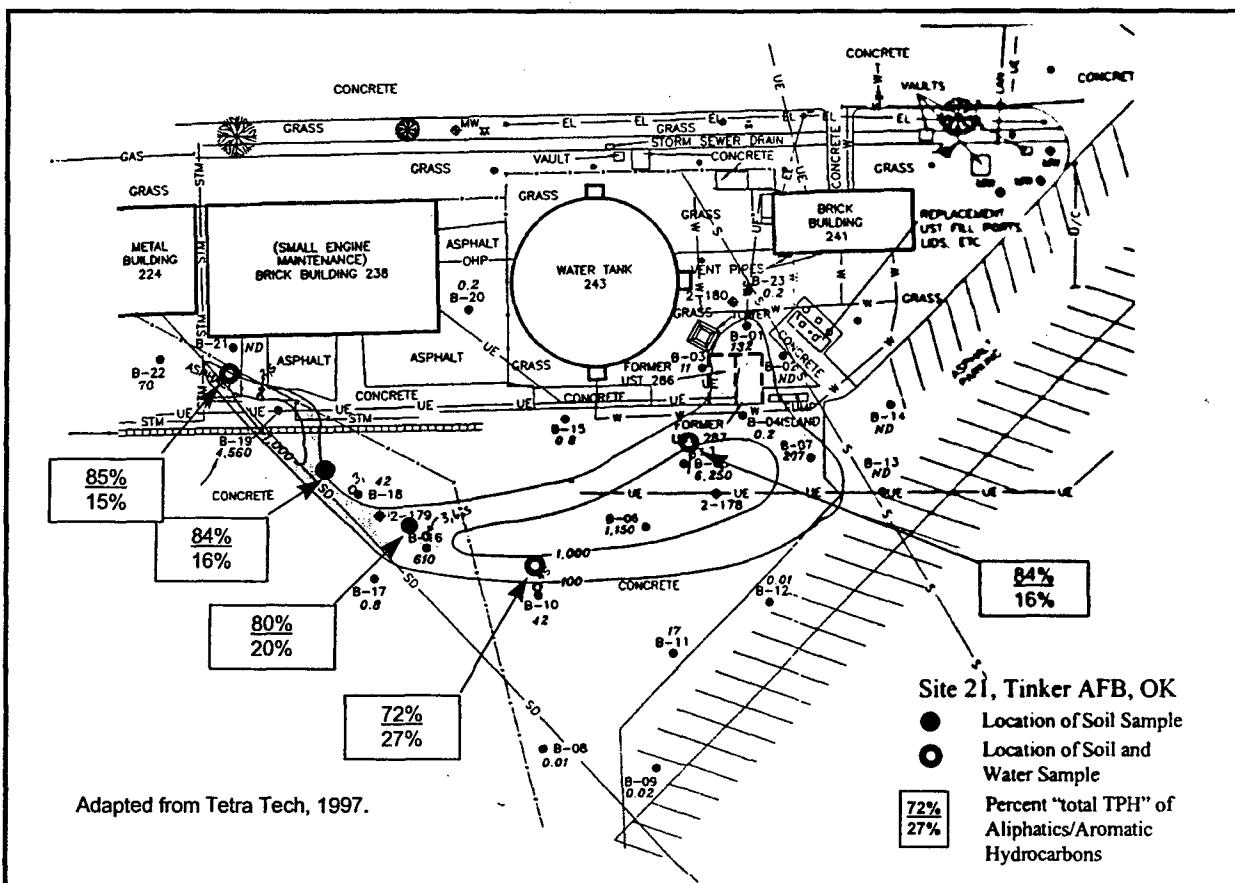
Figure 3.2 Percent Weight of Aliphatic and Aromatic Fractions in Soil (From Direct Method Analysis)
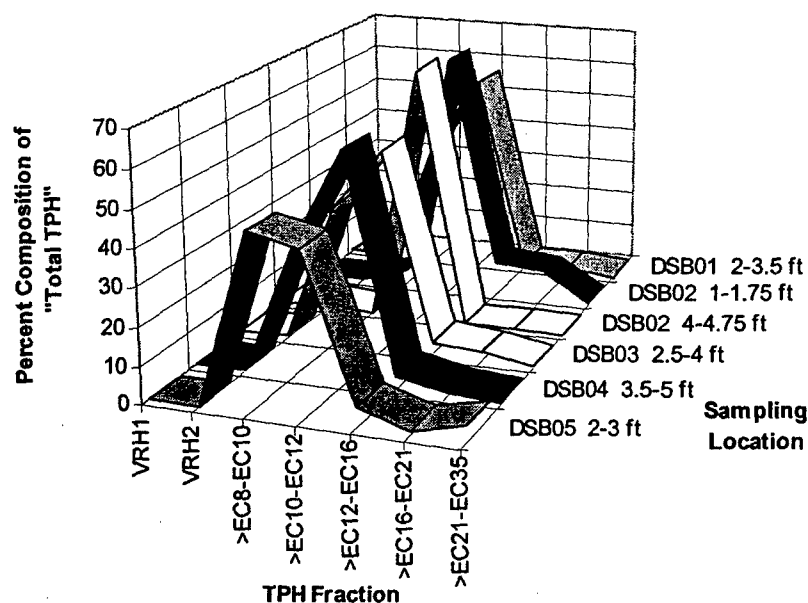
Figure 3.3 Percent of "Whole TPH" of Fractions by Sample Location

Notes:

- VRH1 = Volatile Range Hydrocarbons, Range 1: aliphatics EC5-6 (total) and aromatics EC6-7 (benzene only).
- VRH2 = Volatile Range Hydrocarbons, Range 2: aliphatics => EC6-8 (total minus benzene and toluene) and aromatics => EC7-8 (toluene only).

DSB-02 lies on the edge of the contamination and demonstrates changes in fractions associated with diffusion perpendicular to the groundwater gradient. The hydrocarbon fractions exhibited by this soil boring have low or non-detectable levels of range >EC8 to EC10, but exhibit levels of ranges >EC12 to EC21 hydrocarbon fractions three to four times higher in the upper contaminated zone. These fraction percentages are contrary to what would be expected and are most likely the result of weathering or biodegradation along the lateral edge of the contaminant plume. An alternative explanation for the variance in the hydrocarbon fractions may be a separate source; however, no data exist to confirm a separate source for the contamination in soil boring DSB-02.

3.2.1 Vertical Variability in Hydrocarbon Fractions

Soil samples were collected at a depth below the maximum contamination to ascertain the vertical variability in fractions based on the Direct Method. Depths for the samples were based on PID readings from previous investigations that were much higher than background and were close to the groundwater table. The Direct Method analyses of these soil samples resulted in non-detectable quantities of all the hydrocarbon fractions. These results were due to levels of hydrocarbon contamination lower than the laboratory Limit of Quantitation (LOQ) for the

hydrocarbon fractions. Gasoline and Diesel Range Organics analyses based on Oklahoma modified Method 8015A showed levels of hydrocarbon contamination in these lower samples to range from <1 ppm to 124 ppm total hydrocarbons. Not all lower soil samples were analyzed for GRO and DRO. The lack of data on hydrocarbon fractions from the vertical limits of the contamination precludes developing any conclusions about the vertical variability of the contamination.

3.3 Results of the Comparison of Holding Times

Two samples (i.e., Samples 6 and 11, the duplicate samples from DSB-04, 3.5 to 5 ft BGS) were held 30 days and re-analyzed using the Direct Method. Figure 3.4 compares the results for the original and repeated analyses. The repeated analyses for Sample 6 resulted in detection of aliphatics in the ranges >EC16 to EC35, where the original analyses resulted in non-detectable levels of aliphatic hydrocarbons in those ranges. The repeated analyses of Sample 11 also resulted in detection of aliphatic hydrocarbons in the ranges >EC12 to EC35, where the previous analyses also had resulted in non-detectable levels of aliphatic hydrocarbons in those ranges.
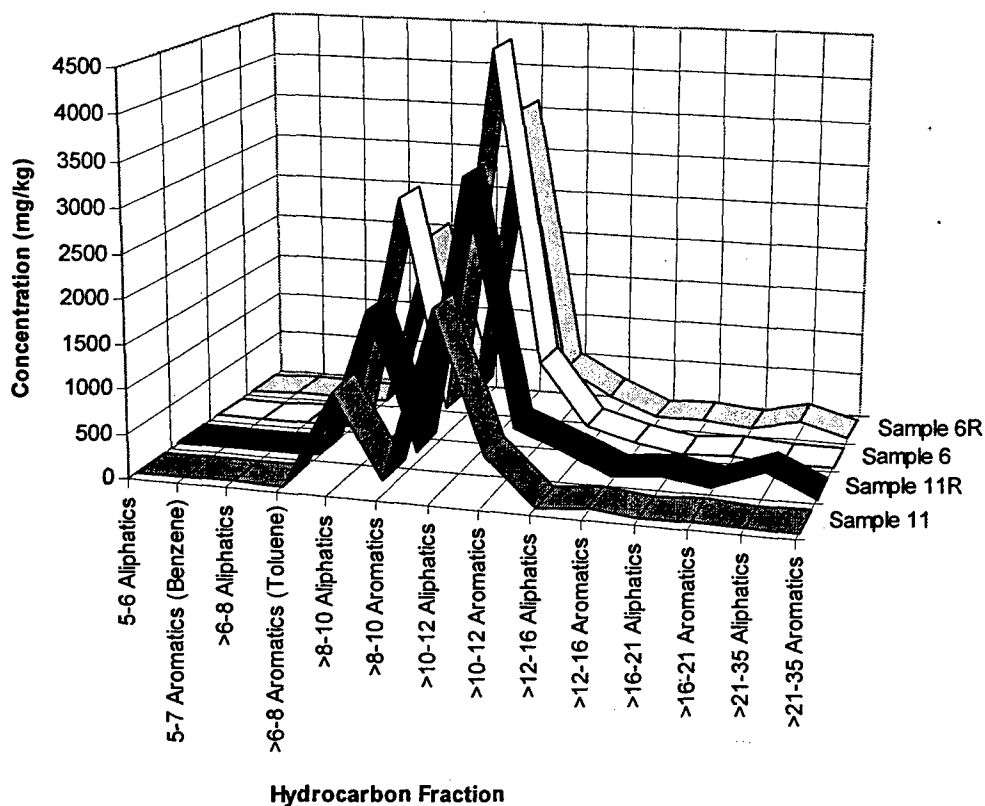
Figure 3.4 Comparison of Holding Times

Table 3.6 presents the percent weight of TPH fractions for the original and repeat samples. The sample results remained very similar in composition. The exception to this trend are the aliphatic >EC12 fractions.

TABLE 3.6 PERCENT WEIGHT OF EC FRACTIONS COMPARISON FOR EFFECTS OF HOLDING TIMES

Effective Carbon Range	Sample 6	Sample 6R	Sample 11	Sample 11R
Aliphatics				
EC5-EC6	ND	ND	ND	ND
>EC6-EC8 ·	ND	ND	ND	ND
>EC8-EC10	36%	33%	33%	30%
>EC10-EC12	59%	58%	62%	58%
>EC12-EC16	3.2%	4.7%	ND	5.2%
>EC16-EC35	ND	3.7%	ND	6.5%
Aromatics				
EC6-EC7	ND	ND	ND	ND
>EC7-EC8	<0.1%	ND	ND	ND
>EC8-EC10	23%	19%	21%	18%
>EC10-EC12	68%	64%	68%	64%
>EC12-EC16	6.5%	7.7%	6.9%	8.1%
>EC16-EC21	3.7%	4.1%	3%	4.3%
>EC21-EC35	ND	ND	ND	ND

Regression analyses on the TPH fractions of Samples 6 and 6R and Samples 11 and 11R resulted in correlation coefficients of R^2 = 0.9939 and R^2 = 0.9764, respectively. Based on this, it can be concluded that holding time had very little effect on results of the Direct Method for ranges >EC8 to EC35 in the given samples. Since only the analysis of Sample 6 (i.e., the sample analyzed within the holding time) resulted in a quantifiable level of lighter hydrocarbons (<EC8), a conclusion cannot be drawn on the impact of holding time on the purgable fractions.

3.4 Analysis of Fate and Transport Prediction

Predictions of concentrations in the groundwater and soils down-gradient from the demonstration project soil borings were calculated based on transport equations in the ASTM guidance (1995). The equations used included soil to groundwater leaching, dissolved phase transport of hydrocarbons, mass of a contaminant sorbed to soils and saturation concentrations in the soils. The equations are provided in the fate and transport discussion of the RBSL calculations, Appendix B.

The predictive capability of these models is dependent upon the following assumptions (TPHCWG, 1998b):

- No degradation (biotic or abiotic) of the chemical in soil or groundwater,

- Simple, linear partitioning of the chemical between soil particles and soil water,
- Uniform soil moisture content with depth (until the capillary fringe),
- No additional dilution of the chemical occurs once it reaches the groundwater table (no lateral dispersion), and
- No free product (NAPL) is present.

The predicted groundwater concentrations yielded significantly different levels than those found in the field. The estimated groundwater concentrations are based on the leaching factor times the concentrations found in the soil for that fraction. The calculations for the leaching factors for each effective carbon range provided groundwater concentrations generally two to three orders of magnitude higher than those found in the groundwater. Previous investigations identified levels of TPH in the groundwater of 1.35 to 0.032 mg/L. Predicted levels of contamination based on the leaching factor equation ranged from 6 to 60 mg/L "whole TPH" in the groundwater. Table 3.7 presents the estimated concentrations in the groundwater based on the leaching factor calculations.

TABLE 3.7 ESTIMATED GROUNDWATER CONCENTRATIONS

EC Range	LF (mg/L) / (mg/kg)	Soil Conc (mg/kg)	Pred GW Conc (mg/L)	Soil Conc (mg/kg)	Pred GW Conc (mg/L)	Soil Conc (mg/kg)	Pred GW Conc (mg/L)
Aliphatic Fractions		DSB-01	DSB-01	DSB-02	DSB-02	DSB-05	DSB-05
EC5-EC6	4.52E-02	2.20E+01	9.95E-01	1.00E-01	4.52E-03	2.20E+01	9.95E-01
>EC6-EC8	9.54E-03	2.20E+01	2.10E-01	1.00E-01	9.54E-04	2.20E+01	2.10E-01
>EC8-EC10	1.22E-03	1.37E+02	1.67E-01	1.36E+01	1.66E-02	1.37E+02	1.67E-01
>EC10-EC12	1.55E-04	8.55E+01	1.32E-02	8.55E+01	1.32E-02	8.55E+01	1.32E-02
>EC12-EC16	7.75E-06	3.81E+01	2.95E-04	1.10E+01	8.53E-05	3.81E+01	2.95E-04
>EC16-EC35	3.89E-08	1.30E+01	5.05E-07	1.30E+01	5.05E-07	1.30E+01	5.05E-07
Total Aliphatic Conc			1.39E+00		3.54E-02		1.39E+00
Aromatic Fractions							
EC6-EC7	1.93E-01	5.00E-01	9.67E-02	3.00E-03	5.80E-04	5.00E-01	9.67E-02
>EC7-EC8	1.55E-01	5.00E-01	7.74E-02	3.00E-03	4.64E-04	5.00E-01	7.74E-02
>EC8-EC10	1.17E-01	1.31E+02	1.53E+01	4.50E+00	5.28E-01	1.53E+02	1.79E+01
>EC10-EC12	1.11E-01	3.20E+02	3.54E+01	2.54E+01	2.81E+00	2.34E+02	2.60E+01
>EC12-EC16	1.02E-01	5.30E+01	5.41E+00	1.10E+01	1.12E+00	4.40E+01	4.49E+00
>EC16-EC21	9.02E-02	4.20E+01	3.79E+00	1.10E+01	9.93E-01	1.10E+01	9.93E-01
>EC21-EC35	7.46E-02	8.31E+00	6.20E-01	8.31E+00	6.20E-01	8.31E+00	6.20E-01
Total Aromatic Conc			6.08E+01		6.08E+00		5.01E+01
"Whole TPH" Conc			6.21E+01		6.11E+00		5.15E+01

Notes:
- Conc = Concentration
- Pred GW Conc = Predicted Groundwater Concentration
- Predicted concentrations in water based on soil concentrations, which are:
  - Results of Analyses if less than C_{sat},
  - Csat if results are greater than C_{sat}, or
  - one half the LOQ for non-detected fractions.

When calculating soil saturation concentrations to estimate the potential for free product at the site, the concentrations found in the field are generally significantly higher than the saturation concentrations. Table 3.8 presents the calculated soil saturation concentrations. The saturation concentrations for the soils indicate a potential for free phase hydrocarbons to exist; however, this was not observed in the soil borings used for water sampling. Based on these findings, an alternative conceptual model was developed.

TABLE 3.8 SOIL HYDROCARBON SATURATION CONCENTRATIONS

Effective Hydrocarbon Range	S Solubility (mg/L)	K_{oc} (cm^3/cm^3)	H_c Henry's Law Constant	k_s	C_{sat} (mg/kg)
Aliphatic Fractions					
EC5-EC6	3.60E+01	7.94E+02	3.40E+01	7.94E+00	309.32
>EC6-EC8	5.40E+00	3.98E+03	5.10E+01	3.98E+01	219.95
>EC8-EC10	4.30E-01	3.16E+04	8.20E+01	3.16E+02	136.59
>EC10-EC12	3.40E-02	2.51E+05	1.30E+02	2.51E+03	85.48
>EC12-EC16	7.60E-04	5.01E+06	5.40E+02	5.01E+04	38.10
>EC16-EC35	1.30E-06	1.00E+09	6.40E+03	1.00E+07	13.00
Aromatic Fractions					
EC6-EC7	1.80E+03	7.94E+01	2.30E-01	7.94E-01	1,627.89
>EC7-EC8	5.20E+02	2.51E+02	2.70E-01	2.51E+00	1,363.74
>EC8-EC10	6.50E+01	1.58E+03	4.90E-01	1.58E+01	1,037.60
>EC10-EC12	2.50E+01	2.51E+03	1.40E-01	2.51E+01	630.69
>EC12-EC16	5.80E+00	5.01E+03	5.40E-02	5.01E+01	291.31
>EC16-EC21	5.10E-01	1.58E+04	1.30E-02	1.58E+02	80.88
>EC21-EC35	6.60E-03	1.26E+05	6.80E-04	1.26E+03	8.31

Notes:
- Table adapted from TPHCWG, 1998b, Table 7
- K_{oc} = organic carbon sorption coefficient

The conceptual model originally developed for the site was based on leaching of contaminants to the groundwater, transport of dissolved contaminants and adsorption of the contaminants on soils in and near the groundwater interface. This conceptual model fit the ASTM RBCA fate and transport framework (1995). However, based on the analytical results, a different conceptual model has been developed. This conceptual model is based on dual phase transport of hydrocarbons without the presence of visible non-aqueous phase liquids (NAPLs).

The NAPLs associated with this transport mechanism are not free product in the sense of petroleum hydrocarbons floating on water, but rather can be considered as hydrocarbons that are moving along the surface of the water and adsorbing to soils, but at concentrations above the saturation limit of the soils. These hydrocarbons have migrated up and down with the groundwater surface as the groundwater level fluctuated with seasons, creating a smear zone. Figure 3.5 provides a drawing of the conceptual model.
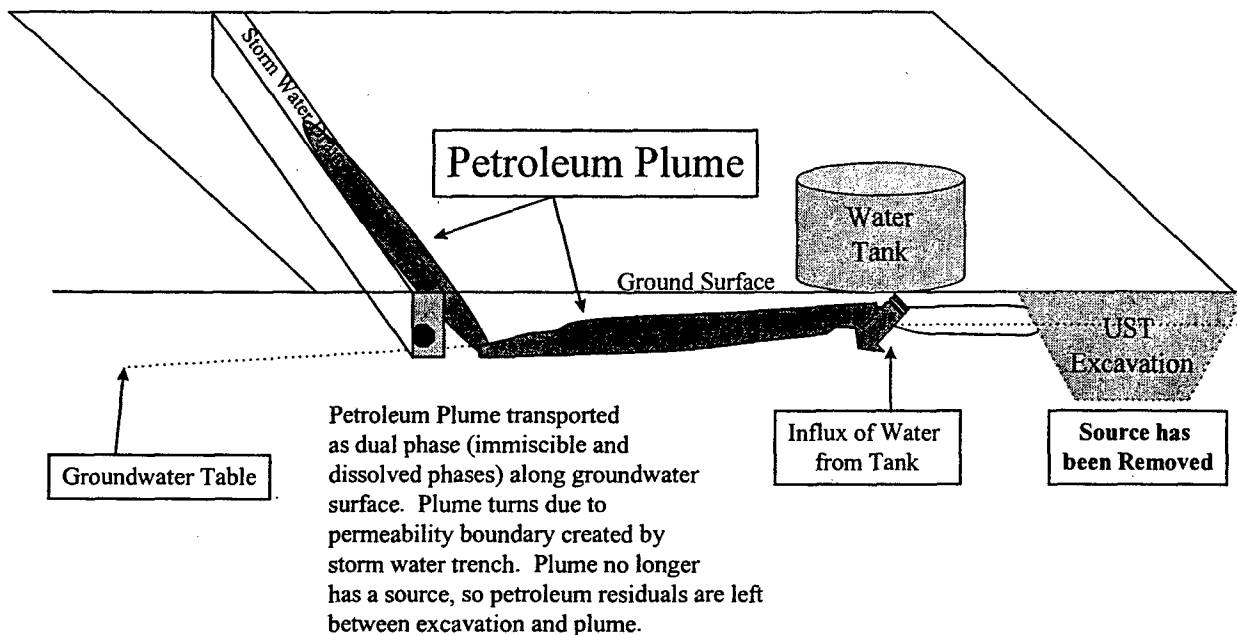
Figure 3.5 Conceptual Model for Site 21 Based on Sample Concentrations

The findings have an impact on the RBSLs generated by the RBCA model. First, the TPHCWG (1998b) states that the saturation concentration is "a delineation point for the applicability of the simple screening models used in this methodology, thus the partitioning equations presented here are not appropriate for soils containing free product." Although this site may not contain free product, the appearance of dual phase transport of the hydrocarbon contamination at this site indicates that the simple screening models may not be predictive. However, the TPHCWG also states that "this approach is not invalid for sites containing NAPLs. For cases where NAPL is present, the upper limit in concentration at saturation in soil vapor and soil moisture must be considered and models relevant to free-phase products applied" (1998b). For this site, models relevant to free-phase product movement would be more applicable than the simple screening level models used, even though free-phase product was not observed in the borings.

Second, the TPHCWG (1998b) states "when total soil concentration exceeds C_{sat}, Raoult's Law states that the concentrations of chemicals in the vapor and moisture phases that are in equilibrium with soil at concentrations greater than saturation are functions of the mole fraction of each contaminant in the separate hydrocarbon phase." This will result in lower C_{sat} values than those calculated using the simple equation provided in Appendix C. Therefore, the RBCA model will be conservative in its calculation of the RBSLs when the concentration in the soils exceeds the C_{sat} value. This impacts the partitioning of the different phases when C_{sat} is exceeded due to limits of the applicability of the Henry's Law Constant.

Based on these impacts of soil concentrations exceeding the saturation concentrations calculated from simple models, it is anticipated that the RBSLs developed by the RBCA model will be very conservative. In order to model the system to more closely reflect the reality of a dual phase transport of petroleum hydrocarbons, equations or models that deal effectively with

29

free-phase petroleum should be identified and included in the Working Group approach. A method to integrate the results of these models into the approach should also be identified to properly utilize the additional equations. Additionally, rules for the use of the free-phase equations should be developed based on concentrations found in the soil in reference to the calculated saturation concentrations for the fractions (C_{sat}).

3.5 Results of Tier 1 and Tier 1-A Risk Characterization

The source of contamination at Site 21 was identified as the former USTs 286 and 287, which contained JP-4 and diesel fuel, respectively. An assessment of available data indicated that soil contamination ranged between 1 and 5.5 feet BGS consistently across the site. Laterally, the plume extends to the west of the original tank pit, but not beyond the underground storm drain. The contamination appears to have followed the west/southwest flow of the groundwater, migrating along the top of the shallow water table. None of the soil samples exceeded OCC Category II cleanup levels for BTEX (5\400\150\1000 mg/kg) but a few soil samples ranged from 2,054 to 15,042 mg/kg, exceeding the OCC cleanup levels for TPH (500 mg/kg). None of the groundwater samples collected at Site 21 exceeded OCC Category II cleanup levels for BTEX (0.05\10\7\1000 mg/L) or TPH (10 mg/L) (Tetra Tech, 1997).

The potential receptors and exposure pathways at this site are very limited due to the concrete covering and the expected land use. The closest residences are approximately 3,200 feet east and north of the site. Residential land use is not anticipated. The impacted area will remain industrial as part of the Base for the foreseeable future. Therefore, potential scenarios assessed included commercial/industrial and construction. The shallow groundwater zone at Site 21 is impacted; however it is not used as a potable water source and contamination does not appear to have migrated off-site or to the aquifer below. Never-the-less, soil leaching to groundwater was evaluated for purposes of demonstration, as it is a common pathway at TPH sites.

Vaporization to outdoor air was evaluated for both a commercial and construction scenario. The likelihood of this pathway would increase if the concrete covering were removed. Inhalation of indoor vapors from impacted soils was also evaluated for commercial workers in Buildings 238 and 224. This is an extremely conservative assumption because these buildings are not located above or directly adjacent to the impacted area. Soil samples taken previously between the edge of the plume and the buildings resulted in nondetects for BTEX and PAHs (TetraTech, 1997). In addition, Building 238 is a maintenance shop, where vapors from degassing engines would be present.

Lastly, direct contact with impacted soils was evaluated under a potential construction scenario. Currently this does not represent a complete exposure pathway due to the concrete cover. Figure 3.6 presents the site exposure pathway analysis.

Figure 3.6 Exposure Pathway Analysis

PRIMARY SOURCES	SECONDARY SOURCES	TRANSPORT MECHANISMS	EXPOSURE PATHWAY	POTENTIAL RECEPTORS
■ **Product Storage**	☐ *Affected Surface Soils (≤3 ft depth)*		■ **Soil** *Dermal Contact Ingestion*	**Exposed Receptors**
■ **Piping / Distribution**		■ *Wind Erosion And Atmospheric Dispersion*		On-Site: ☐ Residential ■ Non-Resid. Habitat Off-Site: ☐ Residential ☐ Non-Resid. Habitat
☐ **Operations**	■ *Affected Subsurface Soils (> 3 ft depth)*	■ *Volatilization and Atmospheric Dispersion*	■ **Air** *Inhalation of Vapor or Dust*	**Exposed Receptors** On-Site: ☐ Residential ■ Non-Resid. Off-Site: ☐Residential ☐ Non-Resid
☐ **Waste Management Unit**	■ *Dissolved Groundwater Plume*	■ *Volatilization and Enclosed-Space Accumulation*		
☐ **Other: SPILL**		■ *Leaching and Groundwater Transport*	■ **Groundwater** *Potable Water Use*	**Groundwater Users** On-Site: ☐ Residential ■ Non-Resid. Off-Site: ☐Residential ☐ Non-Resid.
	☐ *Free-Phase Liquid Plume*	☐ *Mobile Free-Liquid Migration*		
	☐ *Affected Surface Soils, Sediments. or Surface Water*	☐ *Stormwater Surface Water Transport*	☐ **Surface Water** *Recreational Use / Sensitive Habitat*	**Surface Water** On-Site: ☐ Residential ☐ Non-Resid. Off-Site: ☐ Residential ☐ Non-Resid.

REMOVAL / TREATMENT ACTIONS   CONTAINMENT MEASURES   INSTITUTIONAL CONTROLS

Figure 3.6 Exposure Pathway Analysis

The results of Tier 1 evaluations are presented in the following sections as a RBSL and a pathway-specific HI for each soil sample and pathway evaluated. A detailed discussion on the development of RBSLs in presented in Appendix B. The risk results and RBSLs from the model runs are provided in Appendix C. One-half the detection limit for fractions with nondetects was used to develop the RBSLs. RBSLs represent soil concentrations which would not result in unacceptable risk levels. The HI represents a comparison between the TPH concentration and the RBSL as follows:

$$HazardIndex\,(HI) = \frac{TPH\,concentration\,(mg\,/\,kg)}{RBSL_{pathway}\,(mg\,/\,kg)}$$

Due to the shallow depth of groundwater and the obvious reduction in infiltration caused by the concrete cover of the site, a Tier 1-A analysis is also presented on pathways exceeding acceptable risks under the Tier 1 assessment. The Tier 1-A used the limited site-specific fate and transport values provided in the Oklahoma Risk-Based Corrective Action Tier 1 and Tier 1-

A Report (TetraTech, Inc., 1997). Sufficient site-specific information for a Tier 2 assessment was not available. A complete list of the parameters used are provided in Appendix B. The specific parameters modified from the RBCA Tier 1 default values to Tier 1-A include:

- depth of groundwater (from 300 to 143.3 cm),
- depth to subsurface soils (from 100 to 61 cm),
- groundwater Darcy velocity (2500 to 354 cm/yr),
- total soil porosity (from 0.38 to 0.232 cm^3/cm^3),
- volumetric air content in vadose zone soil (from 0.26 to 0.03 cm^3/cm^3),
- soil bulk density (1.7 to 1.88 g/cm^3), and
- infiltration rate (from 30 to 7 cm/yr).

3.5.1 Commercial Scenario Risk Results

Tier 1 RBSLs and HIs for the fractionated samples for the industrial/commercial scenario are presented in Table 3.9. Under the Tier 1 assessment, RBSLs for the soil leaching pathway ranged from approximately 6,222 to 23,798 mg/kg. The volatilization to outdoor air pathway resulted in RBSLs which exceeded 1,000,000 mg/kg for all samples. RBSLs for the direct contact pathway ranged from 5802 to 8906 mg/kg. Indoor air RBSLs were indeed the most restrictive, ranging from 162 to 1228 mg/kg. The target risk level (hazard index) of 1.0 was exceeded for each pathway, except volatilization to outdoor air, for samples 6 and 9, while the indoor air pathway RBSLs were exceed for samples 4, 6, 7, 9 and 11. It should be noted, however, that the indoor air pathway is an unlikely route of exposure for several reasons. Soil samples collected near the buildings in previous investigations indicated non-detectable quantities (Tetra Tech, 1997) and BTEX levels on site were extremely low. Also, Site 21 is located southwest of Bldg. 241. The plume runs southwest on the site and does not appear to run under the building. Therefore, eliminating this pathway as incomplete is valid. However, as stated earlier, the indoor air pathway was presented for the purpose of demonstration.

TABLE 3.9 TIER 1 COMMERCIAL SOIL RBSLs AND HIs

Sample #	TPH present (mg/kg)	Soil Leaching (mg/kg)	HI	Volatilization to Indoor Air (mg/kg)	HI	Direct Contact (mg/kg)	HI	Volatilization to Outdoor Air (mg/kg)	HI
1	377	23798	0.02	1228	0.31	7591	0.05	>100%	NA
2	218	13741	0.02	1201	0.18	5802	0.04	>100%	NA
4	3675	9239	0.40	189	**19.44**	8601	0.43	>100%	NA
6	12397	9803	**1.26**	202	**61.48**	8906	**1.39**	>100%	NA
7	3169	7757	0.41	162	**19.55**	8841	0.36	>100%	NA
9	9101	6222	**1.46**	186	**49.02**	8356	**1.09**	>100%	NA
11	4300	8770	0.49	225	**19.07**	8380	0.51	>100%	NA
Average	4748	11333	0.58	485	24.15	8068	0.55	>100%	NA
Std. Dev.	4489	5963	0.57	499	23.18	1090	0.51	>100%	NA

Notes:
- The fraction-specific RBSLs used to establish "whole TPH" RBSLs were calculated using one half the limit of quantitation for fractions below detection limits.
- HI = Hazard Index (TPH concentration / RBSL)
- Std. Dev. = standard deviation
- NA = not applicable, either HI is insignificant or pathway is incomplete.

The model used to develop indoor air concentrations is highly conservative, assuming steady state diffusion, no attenuation and complete migration. Another important consideration regarding the indoor air pathway is detection limits, particularly for the lightest fractions since one-half the detection limit is used to represent non-detected fractions. Because these fractions are highly mobile, they tend to drive risk for cross-media pathways. Although excellent detection limits for the >EC5 to EC8 aromatics were achieved (<0.006 mg/kg), very high detection limits were reported for the light end aliphatics and the heaviest fractions (both aromatics and aliphatics) for soil samples 4, 6, 7, 9 and 11. For risk assessment purposes, the use of half the detection limits for these aliphatic fractions could not be precluded by GC/MS results, because GC/MS analysis was only run for BTEX and naphthalene.

Tier 1-A RBSLs for the commercial scenario are provided in Table 3.10. As noted in Section 3.5, a few default fate and transport parameters were replaced with more site-specific parameters. The RBSLs for the volatilization to indoor air pathway were increased to above purity (negligible risks). This dramatic increase can be attributed to the slight decrease in the values for soil porosity and air content of the vadose zone used in comparison with the default Tier 1 values. It also demonstrates the conservatism of the indoor air model and how sensitive it is to soil porosity. The effect of the modified Tier 1-A parameters on the direct contact and soil leaching pathways was much less significant. Direct contact RBSLs were slightly reduced and soil leaching RBSLs increased, due the reduced depth to groundwater and subsurface impacted soil assumed.

TABLE 3.10 TIER 1-A COMMERCIAL SCENARIO

Sample #	TPH present (mg/kg)	Soil Leaching (mg/kg)	HI	Volatilization to Indoor Air (mg/kg)	HI	Direct Contact (mg/kg)	HI	Volatilization to Outdoor Air (mg/kg)	HI
1	377	7671	0.05	>100%	NA	7967	0.05	>100%	NA
2	218	4081	0.05	>100%	NA	6100	0.04	>100%	NA
4	3675	5106	0.72	>100%	NA	9120	0.40	>100%	NA
6	12397	4739	**2.62**	>100%	NA	9499	**1.31**	>100%	NA
7	3169	4920	0.64	>100%	NA	9379	0.34	>100%	NA
9	9101	3710	**2.45**	>100%	NA	8927	**1.02**	>100%	NA
11	4300	4074	**1.06**	>100%	NA	8941	0.48	>100%	NA
Average	4748	4900	1.08	>100%	NA	8562	0.52	>100%	NA
Std. Dev.	4489	1324	1.06	>100%	NA	1194	0.48	>100%	NA

Notes:
- The fraction-specific RBSLs used to establish "whole TPH" RBSLs were calculated using one half the limit of quantitation for fractions below detection limits.
- HI = Hazard Index (TPH concentration / RBSL)
- Std. Dev. = standard deviation
- NA = not applicable, either HI is insignificant or pathway is incomplete.

3.5.2 Construction Worker Scenario Risk Results

Table 3.11 presents the Tier 1 results for the Construction Worker Scenario. RBSLs for the soil leaching pathway ranged from 6222 to 23,798 mg/kg. RBSLs for the direct contact pathway ranged from 5492 to 8439 mg/kg. The volatilization to outdoor air pathway resulted in RBSLs exceeding purity (>100%) for all fractionated samples. As described earlier, the indoor air pathway does not represent a plausible pathway for this scenario and therefore was not evaluated. The observed concentrations for Samples 6, 9 and 11 exceeded RBSL levels for the leaching to groundwater pathway. This pathway assumes direct contact with contaminated soil. Both samples 6 and 9 exceeded the RBSLs for the direct contact with soil pathway. The Tier 1-A modifications raised RBSLs for direct contact slightly and decreased the soil leaching RBSLs (see Table 3.12). Again, the assumption of a soil leaching pathway in the construction scenario is extremely conservative since construction workers would not likely come into contact with groundwater. Risks from volatilization to outdoor air were negligible.

TABLE 3.11 TIER 1 CONSTRUCTION WORKER SOIL RBSLs

Sample #	TPH present (mg/kg)	Soil leaching mg/kg	HI	Volatilization to Indoor Air (mg/kg)	HI	Direct Contact (mg/kg)	HI	Volatilization to Outdoor Air (mg/kg)	HI
1	377	23798	0.02	NA	NA	7186	0.05	>100%	NA
2	218	13741	0.02	NA	NA	5492	0.04	>100%	NA
4	3675	9239	0.40	NA	NA	8148	0.45	>100%	NA
6	12397	9803	**1.26**	NA	NA	8439	**1.47**	>100%	NA
7	3169	7,757	0.41	NA	NA	8,376	0.38	>100%	NA
9	9101	6222	**1.46**	NA	NA	7919	**1.15**	>100%	NA
11	4300	8770	0.49	NA	NA	7941	0.54	>100%	NA
Average	4748	11333	0.58	NA	NA	7643	0.58	>100%	NA
Std. Dev.	4489	5963	0.57	NA	NA	1035	0.54	>100%	NA

Notes:
- The fraction-specific RBSLs used to establish "whole TPH" RBSLs were calculated using one half the limit of quantitation for fractions below detection limits.
- HI = Hazard Index (TPH concentration / RBSL)
- Std. Dev. = standard deviation
- NA = not applicable, either HI is insignificant or pathway is incomplete.

TABLE 3.12 TIER 1-A CONSTRUCTION WORKER SOIL RBSLs

Sample #	TPH present (mg/kg)	Soil leaching mg/kg	HI	Volatilization to Indoor Air (mg/kg)	HI	Direct Contact (mg/kg)	HI	Volatilization to Outdoor Air (mg/kg)	HI
1	377	7671	0.05	NA	NA	7522	0.05	>100%	NA
2	218	4081	0.05	NA	NA	5758	0.04	>100%	NA
4	3675	5106	0.72	NA	NA	8612	0.43	>100%	NA
6	12397	4739	**2.62**	NA	NA	8970	**1.38**	>100%	NA
7	3169	4920	0.64	NA	NA	8857	0.36	>100%	NA
9	9101	3710	**2.45**	NA	NA	8431	**1.08**	>100%	NA
11	4300	4074	**1.06**	NA	NA	8443	0.51	>100%	NA
Average	4748	4900	1.08	NA	NA	8085	0.55	>100%	NA
Std. Dev.	4489	1324	1.06	NA	NA	1128	0.51	>100%	NA

Notes:
- The fraction-specific RBSLs used to establish "whole TPH" RBSLs were calculated using one half the limit of quantitation for fractions below detection limits.
- HI = Hazard Index (TPH concentration / RBSL)
- Std. Dev. = standard deviation
- NA = not applicable, either HI is insignificant or pathway is incomplete.

3.5.3 Apportionment of Risks to TPH Fractions

There is considerable variability in the RBSLs calculated. This is attributed to the variability in TPH fraction composition of each sample taken rather than the variability in "Whole TPH"

concentrations reported. It should be noted that the analytical results for Samples 1 and 2 reported the lowest limits of quantitation across all fractions. Although low detection limits (i.e., <0.006 mg/kg) were achieved on all samples for the light end aromatics (which is important for risk assessment purposes because benzene is a carcinogen), high detection limits were reported on the light end aliphatics (i.e., 44 mg/kg) for samples 4, 6, 7, 9 and 11. Previous field demonstrations of the working group's approach have shown that very low levels of light end fractions (i.e., <1% of the "Total" TPH) can contribute as much as 20% of the risk of the entire mixture (RETEC, 1998).

To illustrate the contribution to risk from samples with different TPH fraction compositions, the samples resulting in the lowest and highest RBSLs, Samples 9 and 1, respectively, are presented (see Figures 3.7 and 3.8). The TPH fraction profiles for these samples are considerably different. The majority of TPH in Sample 9 is concentrated in the aliphatic EC8 to EC12 range; however over 95% of the risk for the soil leaching pathway is attributed to the aromatic EC8 to EC12 fractions. Approximately 87% of the risk for the indoor air pathway is attributed to the aromatic EC8 to EC12 range. The distribution of risks for the direct contact pathway closely follows the fractions concentration profiles. A breakdown of the apportioned risks for each pathway evaluated under the Tier 1 Commercial scenario is provided in Table 3.13.
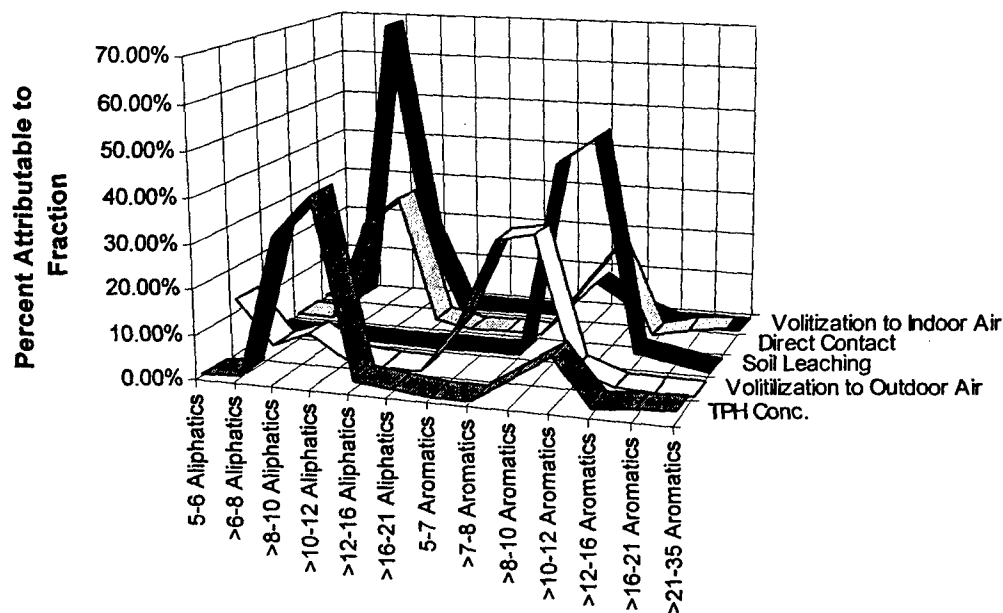
Figure 3.7 Percent Risk Attributable to TPH Fractions - Sample 9 (Lab ID 2926584)
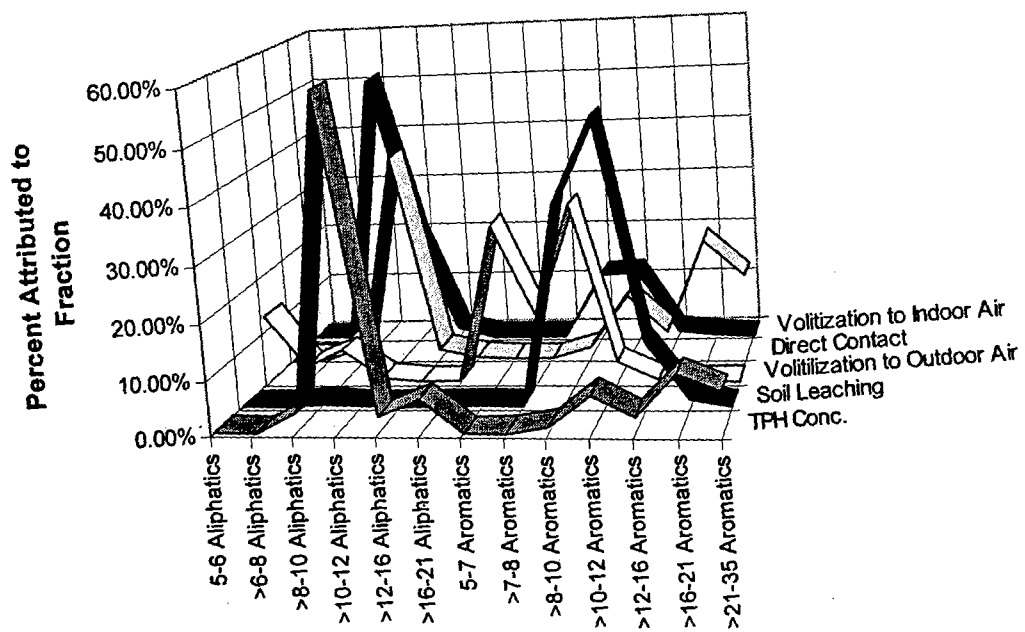
Figure 3.8 Percent Risk Attributable to TPH Fractions - Sample 1 (Lab ID 2926578)

TABLE 3.13 PERCENT CONTRIBUTION OF TPH FRACTIONS TO RISK FOR THE TIER 1 COMMERCIAL SCENARIO (SAMPLES 1 AND 9)

Sample # 9 (Sample ID 2926584)					
Fraction	% of "Whole TPH" Concentration	Soil Leaching % of HI	Volatilization to Outdoor air % of HI	Direct Contact % of HI	Volatization to indoor air % of HI
5-6 Aliphatics	0.18%	0.01%	12.46%	0.00%	0.23%
>6-8 Aliphatics	0.77%	0.02%	2.80%	0.01%	0.42%
>8-10 Aliphatics	32.11%	0.35%	5.98%	23.31%	68.54%
>10-12 Aliphatics	41.70%	0.03%	0.75%	30.27%	18.32%
>12-16 Aliphatics	2.08%	0.00%	0.07%	1.51%	0.19%
>16-21 Aliphatics	0.90%	0.00%	0.00%	0.03%	0.00%
>16-21 Aromatics	1.81%	1.37%	0.01%	4.29%	0.01%
>21-35 Aromatics	2.23%	0.02%	0.00%	5.13%	0.00%
5-7 Aromatics	0.00%	0.11%	10.84%	0.00%	0.02%
>7-8 Aromatics	0.03%	0.26%	30.78%	0.01%	0.06%
>8-10 Aromatics	5.65%	44.37%	32.43%	11.02%	8.88%
>10-12 Aromatics	11.36%	50.49%	3.56%	22.17%	3.24%
>12-16 Aromatics	1.19%	2.97%	0.32%	2.23%	0.07%
>16-21 Aromatics	1.81%	1.37%	0.01%	4.29%	0.01%
>21-35 Aromatics	2.23%	0.02%	0.00%	5.13%	0.00%

Sample #1 (ID 2926578)					
Fraction	% of "Whole TPH"	Soil Leaching % of HI	Volatilization to Outdoor air % of HI	Direct Contact % of HI	Volatization to indoor air % of HI
5-6 Aliphatics	0.03%	0.01%	12.46%	0.00%	0.23%
>6-8 Aliphatics	0.03%	0.00%	2.80%	0.00%	0.10%
>8-10 Aliphatics	3.61%	0.35%	5.98%	2.38%	50.97%
>10-12 Aliphatics	58.67%	0.03%	0.75%	38.69%	20.38%
>12-16 Aliphatics	2.92%	0.00%	0.07%	1.93%	1.78%
>16-21 Aliphatics	6.11%	0.00%	0.00%	0.21%	0.01%
5-7 Aromatics	0.00%	0.08%	28.82%	0.00%	0.03%
>7-8 Aromatics	0.00%	0.03%	12.79%	0.00%	0.01%
>8-10 Aromatics	1.19%	35.90%	32.43%	2.12%	12.43%
>10-12 Aromatics	6.74%	50.49%	3.56%	11.96%	12.72%
>12-16 Aromatics	2.92%	11.71%	0.32%	4.99%	1.07%
>16-21 Aromatics	10.35%	1.37%	0.01%	22.22%	0.28%
>21-35 Aromatics	7.43%	0.02%	0.00%	15.50%	0.00%

The risk and concentration profiles for Sample 1 are similar. However the apportionment of risk is distributed more widely over the TPH fractions, resulting in lower risks overall. The majority of TPH is concentration in aliphatic EC10 to EC12 fraction (approximately 59%); yet 87% of the soil leaching risks are attributed to the aromatic EC12 to EC16 range, 71% of the indoor air risk is attributed to the aliphatic EC8 to EC12 range and 74% of the outdoor air risk is attributed to the aromatic EC5 to EC10 range. The percent contribution to risk for the direct contact pathway conforms consistently to the fraction profile for both samples.

3.5.4 Risk Discussion

Only two Samples (i.e., 6 and 9) exceed risk levels for the soil leaching and direct contact pathways. Both samples were among those with the highest detection limits across all fractions and are therefore likely to be less representative of the actual TPH profile at the site than the other samples. The Working Group approach, however, provided conservative yet meaningful RBSLs which could be applied at this site. The average concentration reported from the fractionated samples did not exceed the average RBSLs for all pathways, with the exception of indoor air for the Tier 1 analyses. The Tier 1-A analysis, however, essentially eliminated the hypothetical risks of this pathway. These findings are in agreement with the Tier 1-A RBCA analysis performed by Tetra Tech (1997). Closure of the site is recommended.

Based on the best levels of detection reported, Samples 1 and 2 appear most suitable for establishing cleanup criteria. Based on the fraction distribution of these samples, risks are at acceptable levels. Although the detection limits of light end aliphatic fractions for the remaining samples were poor for risk assessment purposes, the fraction profiles suggest these samples are less weathered and could be used to establish a separate set of criteria for the southwestern portion of the impacted area.

As noted above, the use of the Tier 1-A parameters resulted in the elimination of risks from the indoor air pathway for the commercial scenario, demonstrating the sensitivity of the model to soil porosity. The Tier 1-A values had less impact on the leaching to groundwater and direct contact pathways; however, soil leaching RBSLs were increased. The contribution to variance by use of these selected values is not known. For example, the Tier 1-A analysis assumes an infiltration rate of 7 cm/yr versus 30 cm/yr used as a Tier 1 default value. The infiltration rate may actually be less than 7 cm/yr vertically, because the site is covered by concrete asphalt. Conversely, vertical infiltration may be greater due to leakage from the water tower. In addition, the uncertainty in the fate and transport models was not evaluated. The ASTM RBCA models, however, are not suited for a Tier 2 analysis of this site, due to the presence of dual phases and the predominance of lateral transport.

3.5.5 Comparison of Oklahoma Tier 1 and Tier 1-A Results

Although the Oklahoma RBCA develops RBSLs for BTEX and naphthalene, whereas the Working Group approach develops one TPH RBSL based on the TPH fractions present, the two assessments are somewhat comparable. BTEX and naphthalene are included in the fractionation results and all are assessed, with the exception of carcinogenic benzene. In this case, benzene was not detected in soil. Therefore, the use of the Working Group approach is very applicable. Some of the individual samples exceeded their comparable RBSL. The soil leaching to groundwater and the indoor air pathways, however, are incomplete. The evaluation of these pathways was included for demonstration purposes since they are common pathways at TPH sites. Only two samples slightly exceeded the direct contact RBSLs. Overall, the average TPH levels detected did not exceed the average RBSLs. Based upon the average concentrations, both the ORBCA and this report arrive at the conclusion that the TPH levels present in the soil do not present unacceptable levels of risk.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Applicability of Working Group Approach to Tinker AFB

The Working Group approach includes analyses of petroleum hydrocarbon contaminated soil and groundwater samples to identify the various TPH fractions present. Using the TPH fractions, RBSLs for applicable exposure pathways are calculated using the ASTM RBCA framework. The approach was developed to be applied to petroleum hydrocarbon spill sites where weathering may have resulted in a loss of more mobile and/or more toxic TPH fractions.

The Working Group approach was demonstrated at Site 21, a former JP-4 and diesel UST site at Tinker AFB, Oklahoma. Soil samples were collected and analyzed for TPH and BTEX using conventional analyses and for TPH fractions using the Direct Method. The results of the conventional and Direct methods correlated well. These data and geotechnical data from previous investigations were used to predict soil and groundwater concentrations downgradient from a known point. The results of the Direct Method analyses and the geotechnical data were used within the ASTM RBCA framework to estimate RBSLs for applicable exposure pathways at the site.

The demonstration of the Working Group approach at this site led to the following conclusions.

- For fine grained sandstone layers, continuous coring may be required to collect adequate sample quantities for analyses; however, the method of choice is the split spoon to avoid heating of the soil during sampling.
- Soil contaminant levels of at least 200 ppm TPH are indicated for useful results from the Direct Method analyses.
- Results at Tinker AFB Site 21 using the Direct Method correlate well with results from conventional TPH and BTEX analyses.
- TPH fractions present along the length of the plume vary due to variations in fraction mobility.
- Little impact on the analytical results for >EC8 to EC35 ranges was found from increased holding times on selected samples.
- Duplicate samples yielded consistent fraction percentages, but the quantified total concentrations varied by nearly a factor of two.
- Fate and transport equations used in the RBCA risk analyses cannot predict the TPH concentrations found in the groundwater and soils at this site. The levels calculated by the equations are very conservative.
- The average RBSLs calculated using the Working Group approach indicate that present levels of TPH contamination are not a hazard to human health and the environment.

4.2 Comparison of Forecasts to Measured Soil / Water Concentrations

An attempt to predict concentrations in the groundwater and soils using the fate and transport equations from the ASTM RBCA standard resulted in concentrations much different than those found in the groundwater and soils at the site. Predicted groundwater concentrations calculated using the leaching factors were two to four orders of magnitude greater than those found in the groundwater from previous investigations. Variations between predicted levels of contamination

40

using the ASTM RBCA fate and transport equations and those actually found led to the development of an alternative conceptual model for the site.

The basic transport mechanisms included in the Working Group approach are leaching of the petroleum hydrocarbon to groundwater, transport in the dissolved phase and volatilization to air in the subsurface pores. The new conceptual model includes transport of free phase contaminants on top of the groundwater table, but not as free product. This conceptual model may be more representative of sites with shallow groundwater tables.

4.3 Risk Summary

Using the Working Group approach for calculating Tier 1 RBSLs, appropriate cleanup levels were developed for Site 21 at Tinker AFB. These values ranged from 162 mg/kg for the indoor air pathway to 23,798 mg/kg for the leaching to groundwater pathway and over 100% TPH for the outdoor air pathway, given a commercial scenario. The RBSLs for a construction worker scenario ranged from 5492 mg/kg for the direct contact pathway to 23,798 for the leaching to groundwater pathway.

The modifications in the Tier 1-A assessment resulted in all indoor air pathway RBSLs exceeding 100% and the leaching to groundwater RBSLs decreasing about half. This was attributed to decrease in the depth to groundwater and subsurface source assumed. For these pathways, the default values were actually much less conservative. Reductions in infiltration rate, soil pore space and Darcy's groundwater velocity were attributed to the dramatic increase in indoor air RBSLs. Changes in the direct contact RBSLs were minimal from Tier 1 to Tier 1-A, as would be expected since this pathway does not depend on factors influencing chemical movement.

The average site concentration from all fractionation samples (i.e., 4748 mg/kg) did not exceed the commercial RBSL for any pathway, with the exception of indoor air. However, it is important to note that this pathway is not likely complete at the given facility. In addition, the highly conservative indoor air RBSLs were driven mainly by nondetects in the lightest fractions (>EC5 to EC10) due to the use of one-half of the detection limit for nondetected fractions. Good detection limits were achieved for all light end aromatics, which tend to drive pathways attributed most to solubility (e.g., leaching), but very high detection limits (<44.0 mg/kg) were reported for light-end aliphatics on four out of the six samples assessed. These fractions contribute significantly to risks attributed to volatilization pathways. The average site concentration did not exceed the average RBSLs for any of the potentially complete pathways, given the construction worker scenario.

An acceptable correlation between the Direct Method and EPA Method 8015 was achieved among the samples collected. This suggests that the RBSLs based on fractionation results could be translated into an equivalent RBSL for TPH measurements at the site using a conventional method. Although the state of Oklahoma requires the assessment of BTEX and PAHs, not TPH, this demonstration shows that the Working Group approach provides a more accurate depiction of risk because it includes all TPH fractions. The resulting RBSLs could be especially useful for this site because of the low levels of BTEX and PAHs detected.

4.4 Recommended Improvements

The Working Group approach is based upon a site-specific sampling plan, analyses utilizing the Direct Method and RBSL development using the ASTM RBCA approach. These three elements together should assist the site manager in assessing the risk to human health and the environment and proposing action for the site that facilitates rapid closure. With heavily weathered TPH sites, in the absence of light-end hydrocarbons (i.e, ranges <EC12), the site manager can propose closure with no further action unless the contaminant concentrations are very high and a residential scenario is required. However, unless the Direct Method of analyses is used, the degree of weathering at the site is unknown.

The achievement of lower laboratory LOQs may improve site assessments. The LOQs of the light-end fractions become very important if one half the detection limit is used to represent nondetected fractions in a risk assessment. Nondetects may drive risk for cross-media pathways if half their detection limits represent greater than 1% of the "whole TPH" concentration. Consistency and repeatability of the method needs to be demonstrated within and between laboratories.

Another improvement that should be incorporated into the method is identification of models addressing dual phase transport of the contaminants in and on top of the groundwater surface. The TPHCWG states "For cases where NAPL is present, the upper limit in concentration at saturation in soil vapor and soil moisture must be considered and models relevant to free-phase products applied" (1998b). However, no models are identified which address this state. Therefore, models relevant to free-phase product transport in water table aquifers should be identified by the Working Group and a method of application of these models within the RBCA framework developed.

5.0 REFERENCES

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TPHCWG, 1998c. A Risk-based Approach for the Management of Total Petroleum Hydrocarbons in Soil, Volume 4: Development of Fraction-Specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for Total Petroleum Hydrocarbons (TPH).

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APPENDIX A

LITHOGRAPHIC LOGS OF SOIL BORINGS

	TPHCWG DEMONSTRATION PROJECT SITE 21, TINKER AFB, OKLAHOMA	O P T E C H
		OPERATIONAL TECHNOLOGIES CORPORATION

LOG OF BORING DSB-01

Project No.:	THSETA DO8	Sampling Method:	Split Spoon Sampler
Logged By:	Tom Heathman	Depth Drilled:	11.0 feet
Drilling Co.:	Layne, Inc.	Depth to Water:	4.05 feet
Driller:	Larry Jernigin	Date Measured:	May 12, 1998
Date Drilled:	May 11, 1998	Surface Elevation:	
Drilling Method:	Auger	TOC Elevation:	Not Applicable

Depth (ft.)	Blows/6"	% Recovery	Samples	Graphic	DESCRIPTION OF MATERIALS	FIELD SCREENING				Monitoring Well
						PID (ppm)	ATHA (ppm)	BTEX (ppb)	Benzene (ppb)	
					Concrete Apron					
	62 102 31- 3"				Silty Sandstone, red brown (2.5YR4/8) very silty, very fine grained, strong odor, Trace oil stain.	>2500				
5	53 144 - 5"				Silty Sandstone, red brown (2.5YR4/8) very silty, very fine grained, no odor, water saturated.	26.4				
10					TD 11.0 Feet, 1530 PM May 11, 1998 Water Sample taken 0830 AM May 12, 1998. Soil Boring left open, no screen.					
15										
20										

O P T E C H

OPERATIONAL TECHNOLOGIES
CORPORATION

LOG OF BORING DSB-02

Project No.:	THSETA DO8
Logged By:	Tom Heathman
Drilling Co.:	Layne, Inc.
Driller:	Larry Jernigin
Date Drilled:	May 11, 1998
Drilling Method:	Auger

Sampling Method:	Split Spoon Sampler
Depth Drilled:	11.75 feet
Depth to Water:	
Date Measured:	
Surface Elevation:	
TOC Elevation:	Not Applicable

Depth (ft.)	Blows/6"	% Recovery	Samples	Graphic	DESCRIPTION OF MATERIALS	FIELD SCREENING				Monitoring Well
						PID (ppm)	ATHA (ppm)	BTEX (ppb)	Benzene (ppb)	
	24 70				Concrete Apron					
					Silty Clay, red brown (2.5YR4/8) very silty, occasional gravel, strong odor, occasional dark oil stain.	480				
5	55 74- 3				Silty Sandstone, red brown (2.5YR4/6) very silty, very fine grained, no odor, no visual stain.	33.4				
10	18 52 80				Silty Sand, very fine grained, red brown, no odor or stain. Clay, gray (1GLEY8/1), in discontinuous layers and round inclusions, in red brown silghtly silty clay, occasional carbonaceous material, no odor.	20				
					TD 11.75 Feet, 1050 AM May 11, 1998					
					Water Sample taken 1320 PM May 11, 1998. Soil Boring left open, no screen.					
15										
20										

TPHCWG DEMONSTRATION PROJECT
SITE 21, TINKER AFB, OKLAHOMA

O P T E C H

OPERATIONAL TECHNOLOGIES
CORPORATION

LOG OF BORING DSB-03

Project No.:	THSETA DO8	Sampling Method:	Continuous Coring	
Logged By:	Tom Heathman	Depth Drilled:	10.0 feet	
Drilling Co.:	Layne, Inc.	Depth to Water:		
Driller:	Larry Jernigin	Date Measured:		
Date Drilled:	May 11, 1998	Surface Elevation:		
Drilling Method:	Auger	TOC Elevation:	Not Applicable	

Depth (ft.)	Blows/6"	% Recovery	Samples	Graphic	DESCRIPTION OF MATERIALS	FIELD SCREENING				Monitoring Well
						PID (ppm)	ATHA (ppm)	BTEX (ppb)	Benzene (ppb)	
					Concrete Apron					
					Silty Sandstone, red brown (2.5YR4/8), very silty, very fine grained, occasionally hard, strong odor, occasional dark oil stain.	>2500				
5										
					Silty Sandstone, red brown (2.5YR4/8) very silty, very fine grained, no odor, no oil stain.	44				
10					TD 10.0 Feet, 1700 PM May 11, 1998					
15										
20										

TPHCWG DEMONSTRATION PROJECT
SITE 21, TINKER AFB, OKLAHOMA

O P T E C H
OPERATIONAL TECHNOLOGIES
CORPORATION

LOG OF BORING DSB-04

Project No.:	THSETA DO8		Sampling Method:	Continuous Coring
Logged By:	Tom Heathman		Depth Drilled:	5.0 feet
Drilling Co.:	Layne, Inc.		Depth to Water:	
Driller:	Larry Jernigin		Date Measured:	
Date Drilled:	May 12, 1998		Surface Elevation:	
Drilling Method:	Auger		TOC Elevation:	Not Applicable

Depth (ft.)	Blows/6"	% Recovery	Samples	Graphic	DESCRIPTION OF MATERIALS	FIELD SCREENING PID (ppm)	FIELD SCREENING ATHA (ppm)	FIELD SCREENING BTEX (ppb)	FIELD SCREENING Benzene (ppb)	Monitoring Well
					Concrete Apron					
5					Silty Sandstone, red brown (2.5YR4/8), very silty, very fine grained, occasionally hard, well cemented in part, moderate odor, no visual stain.	544				
					TD 5.0 Feet, 1130 AM May 12, 1998					
10										
15										
20										

TPHCWG DEMONSTRATION PROJECT
SITE 21, TINKER AFB, OKLAHOMA

O P T E C H
OPERATIONAL TECHNOLOGIES CORPORATION

LOG OF BORING DSB-05

Project No.:	THSETA DO8	Sampling Method:	Continuous Coring
Logged By:	Tom Heathman	Depth Drilled:	9.0 feet
Drilling Co.:	Layne, Inc.	Depth to Water:	
Driller:	Larry Jernigin	Date Measured:	
Date Drilled:	May 12, 1998	Surface Elevation:	
Drilling Method:	Auger	TOC Elevation:	Not Applicable

Depth (ft.)	Blows/6"	% Recovery	Samples	Graphic	DESCRIPTION OF MATERIALS	PID (ppm)	ATHA (ppm)	BTEX (ppb)	Benzene (ppb)	Monitoring Well
					Concrete Apron					
					Coarse Sand Fill Material					
					Silty Sandstone, red brown (2.5YR4/8), very silty, very fine grained, soft, strong odor, streaks of dark oil stain.	>2500				
5										
					Silty Sandstone, occassionally light tan (7.5YR8/2) very silty, fine to very fine grained, very hard, slight odor, no oil stain; sample steaming when removed from core barrel.	846				
10					TD 9.0 Feet, 0930 AM May 12, 1998 Water Sample taken 1330 PM May 12, 1998. Soil Boring left open, no screen.					
15										
20										

APPENDIX B RBSL CALCULATIONS

The procedure for calculating a TPH RBSL for cross-media pathways based upon summing the risk from each fraction is complex. Please note that the following procedure is only appropriate for calculation of RBSLs for cross-media pathways since it sets as an upper limit for the RBSL the degree of saturation, which does not limit exposure for direct routes such as soil ingestion, dermal exposure, and inhalation of particulates. An additional procedure used to calculate exposure for direct pathways is also provided. These procedures are based on Volume II of the TPH Criteria Working Group publications.

Cross-media Pathways

Partitioning qualities govern how a chemical interacts with its environment. Specific physical properties responsible include solubility, vapor pressure, sorption coefficient and Henry's Law Constant. A brief discussion of the role these parameters play in basic partitioning in the environment is provided in the following paragraphs. The fraction-specific values for each of the described fate and transport parameters is provided in Table 3-1. The equations used to develop these fate and transport properties are available in the TPH Criteria Working Group "Volume III. Selection of Representative TPH Fractions Based on Fate and Transport Considerations" (1998).

The solubility of aromatic hydrocarbons, for any EC number, is generally greater than that of aliphatic hydrocarbons, especially at high EC values. The variability in solubility around any given EC value is about an order of magnitude. The higher solubility of the aromatics means that aromatic hydrocarbons are more likely to be present as dissolved constituents in groundwater than are the corresponding aliphatic hydrocarbons.

The soil-water sorption coefficient (k_s) expresses the tendency of a chemical to be adsorbed onto a soil particle. The magnitude of the sorption coefficient for most soil/water systems is a function of the hydrophobicity of the chemical (as indicated by its solubility) and the organic carbon content of the soil. For non-ionic, hydrophobic chemicals such as petroleum hydrocarbons, the primary property controlling sorption is the organic carbon content (f_{oc}) of the soil.

In general, aliphatic fractions are more likely to remain bound to a soil particle than the aromatic fraction of an equivalent EC. This tendency was previously indicated by the low solubility observed for aliphatic fractions. The majority of log k_{oc} (carbon-water sorption coefficient) values presented in Table 3-1 were derived from the octanol-water partitioning coefficient.

There is very little difference in vapor pressure between aliphatic and aromatic constituents of an equivalent EC. In effect, the EC and vapor pressure are closely related. This relationship is expected because both EC and vapor pressure are largely functions of a compound's boiling point.

The Henry's law constant (H_c) is definable as an air-water partitioning coefficient and may be measured as the ratio of a compound's concentration in air to its concentration in water at equilibrium. Aliphatics and aromatics behave differently based on Henry's law constant. For aromatic fractions, the Henry's law constant decreases with increasing EC; for aliphatic fractions, the Henry's law constant is virtually unaffected by EC. In general, aliphatic hydrocarbons are less soluble and more volatile than aromatic hydrocarbons. It is important to note, however, that benzene, an aromatic compound, is very volatile and more toxic than the

corresponding aliphatic fractions. Therefore, when present, benzene is likely to drive risk calculations for pathways involving volatilization from soil or groundwater.

The parameters described above are combined into simple fate and transport models to evaluate the partitioning and migration of chemicals for the different applicable pathways. For leaching and volatilization pathways where transport and therefore exposure are maximized at the saturation concentration for specific fractions, the following equations are solved. These three equations were adapted from Volume 5 of the Working Group's publications (TPHCWG, 1999).

$$HI = \sum_{i=1}^{i=n} HQ_i = \sum Min\left(\frac{f_i C_{TPH}}{RBSL_i}, \frac{C_{sat,i}}{RBSL_i}\right) \leq 1 \quad \text{given,} \qquad \text{(Equation B-1)}$$

$$\sum_{i=1}^{i=13} f_i = \sum \frac{C_i}{C_{TPH}} = 1 \qquad \text{(Equation B-2)}$$

where:

HI	=	Hazard Index (typically $\leq$ 1) [unitless]
n	=	number of fractions (13 total) [unitless]
HQ_i	=	Hazard Quotient for i^{th} TPH fraction [unitless]
f_i	=	Percent Weight of ith TPH fraction in total TPH mixture [unitless]
C_{TPH}	=	Concentration of TPH mixture
$C_{sat,i}$	=	Saturation concentration for i^{th} TPH fraction (mg/kg)
$RBSL_i$	=	Tier 1 risk-based screening level for i^{th} TPH fraction (mg/kg)

The saturation concentration is defined by Equation B-3:

$$C_{sat,i}[mg/kg] = \frac{S_i}{\rho_s}\left[H_{c,i}\theta_{as} + \theta_{ws} + k_{s,i}\rho_s\right] \qquad \text{(Equation B-3)}$$

where:

S_i	=	Fraction effective solubility [mg/L]
ρ_s	=	Soil Bulk Density [g/cm^3]
$H_{c,i}$	=	Henry's Constant for i^{th} TPH fraction [atm-m^3/mol]
θ_{as}	=	Volumetric air content of the soil [cm^3/cm^3]
θ_{ws}	=	Volumetric water content of the soil [cm^3/cm^3]
$k_{s,i}$	=	Soil sorption coefficient for i^{th} TPH fraction ($k_{oc}*f_{oc}$) [cm^3/g]

Note: The effective solubility of a hydrocarbon fraction is equal to the fraction's solubility limit multiplied by the mole fraction of the hydrocarbon fraction in the mixture (i.e., TPH).

The value obtained for C_{sat} will vary considerably if the effective C_{sat} of each fraction present in the sample is considered through the use of Raoult's law. Equations B-1 through B-3 are iteratively solved for each TPH fraction, which is the additive mixture RBSL for the soil sample.

Residual saturation is the point at which any increase in chemical concentration will not change the risk, up until the point at which free product migration becomes an issue. For purposes of comparing RBSLs obtained using different analytical fractionation methods, such as the MADEP TPH Method, Raoult's law was not used to calculate the RBSLs presented in the following sections.

Soil Leaching to Groundwater Pathway

Leaching of contaminants from impacted soil into groundwater through infiltrating water is one exposure pathway evaluated in the RBCA analysis. Soil RBSLs are calculated to be protective of groundwater quality. This involves: 1) calculating a groundwater RBSL (RBSL$_{gw}$) to determine an acceptable water concentration, 2) calculating a leachate concentration protective of groundwater (based on the groundwater RBSL), and 3) calculating a soil concentration which would result in this leachate concentration. Equation B-4 (adapted from ASTM, 1995) calculates the ingestion RBSL$_{gw}$ for each TPH fraction. The RBSL$_{gw}$ is based on a target hazard quotient of 1.0. Exposure parameters are provided in Table B-1. RfDs for the fractions are listed in Table 3-2.

$$RBSL_{gw,i}\left[\frac{mg}{L-water}\right] = \frac{THQ \times RfD_{o,i} \times BW \times AT_n \times 365^{days}/_{yr}}{IR_{water} \times EF \times ED}$$

(Equation B-4)

where:

THQ	=	Target hazard quotient [unitless] = 1
RfD$_{o,i}$	=	Oral chronic reference dose for i[th] TPH fraction [mg/kg-day]
BW	=	Body weight [kg]
AT$_n$	=	Averaging time for noncarcinogens [yrs]
IR$_{water}$	=	Daily ingestion rate [L/day]
EF	=	Exposure frequency [days/yr]
ED	=	Exposure Duration [yrs]

TABLE B-1 TIER 1 DEFAULT EXPOSURE FACTORS

Name	Parameter	Units	Recreational Scenario	Commercial Scenario
Averaging Time: non-carcinogens	AT_n	y	25	25
Body Weight	BW	kg	70	70
Exposure Duration	ED	y	30	25
Exposure Frequency	EF	days/y	45	250
Ingestion rate: soil	IR_{soil}	mg/day	50	50
Inhalation Rate: air-indoor	IR_{air-in}	m^3/day	20	20
Inhalation Rate: air-outdoor	$IR_{air-out}$	m^3/day	20	20
Ingestion rate: water	IR_{water}	L/day	0.05	1
Soil Adherence Factor	M	mg/cm^2	0.5	0.5
Dermal Absorption Factor	$RAF_{d,i}$	-	c.s.	c.s.
Oral Absorption Factor	RAF_o	-	1	1
Skin surface area	SA	cm^2/day	3160	3160
Target Hazard Quotient for Individual Constituents.	THQ	-	1	1

Note: c.s. = chemical specific

ED, EF, and IR_{water} for recreational exposure scenario were extracted from http://risk.1sd.ornl.gov/homepage/tm/for_rec_wa.shtml. All other exposure factors for recreational scenario have been set equal to the commercial scenario factors as shown in the above table.

The analytical model used to estimate soil leaching to groundwater determines the partitioning of a constituent into water, vapor and sorbed phases based on the physical and chemical properties of the constituent. In this model, infiltrating water migrates through contaminated soils in the vadose zone. At this point, some of the contaminant partitions from the soil or vapor transfer into the water phase. This leachate is then assumed to migrate completely and instantaneously into groundwater. Some dilution of the leachate is included using an attenuation factor based on infiltration rate, groundwater velocity, source width and height of the mixing zone in the water column. Equation B-5 describes this attenuation factor (AF).

$$AF = \left[1 + \frac{U_{gw}\delta_{gw}}{IW}\right]$$ (Equation B-5)

where:

U_{gw} = Groundwater velocity [ft/day]
δ_{gw} = Height of groundwater mixing zone [ft]
I = Precipitation infiltration rate [ft/day]
W = Width of the source area parallel to the mixing zone [ft]

Partitioning into the three phases, soil, water and air, is governed by the partitioning factor. As Henry's law constant is applicable only to dilute solutions, the use of this model is not appropriate when free phase liquid is present. The partitioning factor (PF) for each TPH fraction is shown in Equation B-6.

$$PF_i = \frac{[\theta_{ws} + k_{s,i}\rho_s + H_{c,i}\theta_{as}]}{\rho_s}$$

(Equation B-6)

where,

θ_{ws} = Soil volumetric water content [cm^3/cm^3]
$k_{s,i}$ = Soil sorption coefficient (k_{oc}*f_{oc}) for ith TPH fraction [cm^3/g]
ρ_s = Soil density [g/cm^3]
$H_{c,i}$ = Henry's Constant for ith TPH fraction [atm-m^3/mol]
θ_{as} = Soil volumetric air content [cm^3/cm^3]

The inverse of the product of PF multiplied by AF, which accounts for dilution of leached water into underlying groundwater, is termed the soil to water leaching factor (LF$_{sw}$). The ultra-conservative leaching model assumes that no attenuation of leachate occurs from the vadose to the saturated zone. In fact, biological degradation of the constituent or repartitioning onto soil or into the vapor phase are all likely to occur as the leachate migrates to groundwater. Other assumptions of the model include: 1) a constant chemical concentration in the subsurface soils, 2) linear equilibrium partitioning within the soil matrix between sorbed, dissolved and vapor phases, 3) steady-state leaching from the vadose zone to groundwater, and 4) steady state, well-mixed dispersion of the leachate within the groundwater mixing zone. Therefore the LF$_{sw}$, which governs the movement of contaminants from soil to infiltrating water, incorporates both the PF and the AF, in Equation B-7:

$$LF_{sw,i} = \frac{\rho_s}{[\theta_{ws} + k_{s,i} + H_{c,i}\theta_{as}]\left(1 + \frac{U_{gw}\delta_{gw}}{IW}\right)}$$

(Equation B-7)

where:

LF$_{sw,i}$ = leaching factor for ith TPH fraction [mg/L-H$_2$O / mg/kg-soil]

Parameters for cross-media pathways are provided in Table B-2. Equations B-5 through B-8 were adapted from ASTM's risk-based corrective action (RBCA) standard guide (1995). Once the LF has been established, fraction-specific soil RBSLs may be calculated as follows:

$$RBSL_{s,i}\left[\frac{mg}{kg-soil}\right] = \frac{RBSL_{gw,i}\left[\frac{mg}{L-air}\right]}{LF_{sw,i}}$$

(Equation B-8)

TABLE B-2 PARAMETERS FOR CROSS-MEDIA RBSL CALCULATIONS

Description	Parameter	Units	Tier 1 Default Values
Ambient air mixing zone height	δ_{air}	cm	200
Areal fraction of cracks in foundations/walls	η	cm^2/cm^2	0.01
Depth to subsurface soil sources	L_S	cm	100
Diffusion coefficient in air	D^{air}_i	cm^2/s	c.s.
Diffusion coefficient in water	D^{wat}_i	cm^2/s	c.s.
Enclosed space air exchange rate	ER	1/s	0.00023
Enclosed space foundation or wall thickness	L_{crack}	cm	15
Enclosed space volume/infiltration area ratio	$L_{B,i}$	cm	300
Fraction of organic carbon in soil	f_{oc}	cm^3/cm^3	0.01
Groundwater Darcy velocity	U_{gw}	cm/yr	2500
Groundwater mixing zone thickness	δ_{gw}	cm	200
Henry's Law Constant	$H_{c,i}$	(cm^3/cm^3)	c.s.
Infiltration rate of water through soil	I	cm/yr	30
Particulate Emission Rate	$VF_{p,i}$	$\frac{(mg/m^3)}{(mg/kg)}$	6.9×10^{-14}
Soil bulk density	ρ_s	g/cm^3	1.7
Soil-water sorption coefficient	$k_{s,i}$	cm^3/g	$f_{oc} \times k_{oc}$
Total soil porosity	θ_T	cm^3/cm^3	0.38
Volatilization Factor (Vapor Emission Rate)	$VF_{ss,i}$	$\frac{(mg/m^3)}{(mg/m^3)}$	0.26
Volumetic air content in vadose zone soils	θ_{as}	cm^3/cm^3	0.26
Volumetric air content in foundation cracks	θ_{acrack}	cm^3/cm^3	0.26
Volumetric water content vadose zone soils	θ_{ws}	cm^3/cm^3	0.12
Volumetric water content: foundation cracks	θ_{wcrack}	cm^3/cm^3	0.12
Width of source area parallel to flow direction	W	cm	1500
Wind speed above ground surface	U_{air}	cm/s	225

Notes: c.s. = chemical specific
m.s. = media specific

Volatilization to Indoor Air Pathway

The mathematical model used to estimate volatilization from soil to indoor air is based upon the partitioning of a constituent into water, vapor and sorbed phases as determined by the physical properties of the chemical. The model accounts for the contaminant partitioning into soil pore gas and migrating through the vadose zone to the base of a building foundation. From there the gas diffuses through cracks in the foundation and into the building air space, where exposure through inhalation may occur.

The first step in calculating a soil RBSL for the indoor air pathway requires the calculation of an air concentration or RBSL, which is protective of indoor air quality (based on a target HQ of 1.0). Indoor air RBSLs are calculated for each TPH fraction and then a whole TPH RBSL is calculated based on the percent composition of each fraction. Equation B-9 is used to calculate the air RBSLs for TPH fractions. Parameter values are presented in Table B-2.

$$RBSL_{air,i}\left[\frac{\mu g}{m^3 air}\right] = \frac{THQ \times RfD_{i,i} \times BW \times AT_n \times 365\frac{days}{yr} \times 10^3 \frac{\mu g}{mg}}{IR_{air} \times EF \times ED}$$

(Equation B-9)

where:
THQ	=	Target hazard quotient [unitless] = 1
$RfD_{i,i}$	=	Inhalation chronic reference dose for i^{th} TPH fraction [mg/kg-day]
BW	=	Body weight [kg]
AT_n	=	Averaging time for noncarcinogens [yrs]
IR_{air}	=	Daily inhalation rate [m³/day]
EF	=	Exposure frequency [days/yr]
ED	=	Exposure Duration [years]

The second step in calculating a soil concentration ($RBSL_{soil}$) which will result in an acceptable indoor air concentration ($RBSL_{air}$) is to model the transport of contaminants from the vadose soil to indoor air. This model is extremely conservative, assuming: 1) a constant chemical concentration in subsurface soils; 2) linear equilibrium partitioning in the soil between sorbed, dissolved and vapor phases; and 3) steady-state vapor- and liquid-phase diffusion through the vadose zone and foundation cracks. In addition, the model assumes that vapors migrate completely and instantaneously into the building, i.e., no attentuation occurs. It does not account for any biodegradation and soil sorption which could occur as the vapor migrates through the vadose zone.

Dilution of vapor is expected to occur between the source and the building. Therefore the following diffusion coefficient in soil (D^{eff}_s) for each TPH fraction is used (see Equation B-10).

$$D_{s,i}^{eff}\left[\frac{cm^2}{s}\right] = D_i^{air}\frac{\theta_{as}^{3.33}}{\theta_T^2} + D_i^{wat}\frac{1}{H_{c,i}} \times \frac{\theta_{ws}^{3.33}}{\theta_T^2}$$

(Equation B-10)

where:

D_i^{air} = Diffusion coefficient in air for i^{th} TPH fraction [cm^2/sec]

θ_{as} = Soil volumetric air content [cm^3-air/cm^3-soil]

θ_T = Total soil porosity [cm^3/cm^3]

D_i^{wat} = Diffusion coefficient in water for i^{th} TPH fraction [cm^2/sec]

$H_{c,i}$ = Henry's constant for i^{th} TPH fraction [cm^3-air/cm^3-soil]

θ_{ws} = Soil volumetric water content [cm^3-water/cm^3-soil]

The diffusion of the pore gas through cracks in the foundation is governed by Equation B-11. Equations B-9 through B-11 were adapted from ASTM RBCA (1995).

$$D_{crack,i}^{eff}\left[\frac{cm^2}{s}\right] = D_i^{air}\frac{\theta_{acrack}^{3.33}}{\theta_T^2} + D_i^{wat}\frac{1}{H_{c,i}} \times \frac{\theta_{wcrack}^{3.33}}{\theta_T^2}$$

(Equation B-11)

where:

D_i^{air} = Diffusion coefficient in air for i^{th} TPH fraction [cm^2/sec]

θ_{acrack} = Volumetric air content in foundation [cm^3-air/cm^3]

θ_T = Total soil porosity [cm^3/cm^3]

D_i^{wat} = Diffusion coefficient in water for i^{th} TPH fraction [cm^2/sec]

$H_{c,i}$ = Henry's constant for i^{th} TPH fraction [cm^3-air/cm^3-soil]

θ_{wcrack} = Volumetric water content in foundation [cm^3-water/cm^3]

Chemical Partitioning

Equation B-12 accounts for the movement of chemicals from the soil into the vapor phase of the soil pore space. This is defined as the partitioning factor (soil/vapor phase) and is fraction specific.

$$PF_{s-v,i} = \frac{H_{c,i}\rho_s}{\theta_{ws} + k_{s,i}\rho_s + H_{c,i}\theta_{as}}$$

(Equation B-12)

where:

$PF_{s-v,i}$ = Soil/Vapor phase partitioning factor for i^{th} TPH fraction [unitless]

$H_{c,i}$ = Henry's Constant for i^{th} TPH fraction [cm^3-water/cm^3-air]

ρ_s = Soil bulk density [g/cm^3]

θ_{ws} = Soil volumetric water content [cm^3/cm^3]

$k_{s,i}$ = Soil sorption coefficient (K_{oc}·T_{oc}) for i^{th} TPH fraction [cm^3/g]

θ_{as} = Soil volumetric air content [cm^3/cm^3]

The diffusion coefficients and partitioning factor are combined to yield a subsurface soil to enclosed space volatilization factor (VF$_{sesp}$) for each TPH fraction. VF$_{sesp}$ takes into account partitioning, diffusion in the vadose zone, effective diffusion into an enclosed space and adds terms for accumulation of vapors in the enclosed space (see Equation B-13).

$$VF_{sesp,i} = \frac{(PF_{s-v,i})\dfrac{D_{s,i}^{eff}/L_s}{ER \times L_B}}{1 + \dfrac{D_{s,i}^{eff}/L_s}{ER \times L_B} + \dfrac{D_{s,i}^{eff}+L_s}{(D_{crack,i}^{eff}/L_{crack}) \times \eta}} \times 10^3 \left[\frac{cm^3 - kg}{m^3 - g}\right] \qquad \text{(Equation B-13)}$$

where:

PF$_{s-v,i}$ = Soil/Vapor phase partitioning factor for ith TPH fraction [unitless]

D$^{eff}_{s,i}$ = Effective diffusion coefficient in soil for ith TPH fraction [cm^2/s]

L$_s$ = Depth to subsurface soil sources [cm]

ER = Enclosed-space air exchange rate [s^{-1}]

L$_B$ = Enclosed-space volume/infiltration area ratio [cm]

D$^{eff}_{crack,i}$ = Effective diffusion coefficient through foundation cracks for ith TPH fraction [cm^2/s]

L$_{crack}$ = Enclosed-space foundation or wall thickness [cm]

η = Areal fraction of cracks in foundation/walls [cm^2/cm^2]

Values in these calculations are provided in Table B-2. The term VF$_{sesp}$, when combined with the allowable concentration of contaminant in the air space (RBSL$_{air}$), determines the maximum allowable concentration in the subsurface soil source area for each TPH fraction. The RBSL for the volatilization to indoor air pathway (RBSL$_{svin}$) is shown in Equation B-14. Equations B-12 through B-14 were adapted from ASTM RBCA (1995).

$$RBSL_{svin,i}\left[\frac{mg}{kg - soil}\right] = \frac{RBSL_{air,i}\left[\frac{mg}{m^e - air}\right]}{VF_{sesp,i}} \qquad \text{(Equation B-14)}$$

Volatilization to Outdoor Air Pathway

The volatilization to outdoor air model is similar to the indoor air model. It assumes contaminants partition into soil pore gas that migrates through the vadose zone to the surface and mixes with the ambient air. Dispersion into ambient air is modeled using a "box model", which is typically valid for source widths of less than 100 feet parallel to wind direction. Steady-state well-mixed atmospheric dispersion of the vapors within the breathing zone is assumed. Other assumptions listed for the indoor air model include linear equilibrium partitioning, steady-state vapor diffusion through the vadose zone and no attenuation of the chemical as it migrates through the vadose zone.

The calculation of a soil RBSL protective of outdoor air quality is similar to that used for the indoor air pathway. A volatilization factor for ambient air (VF$_{samb}$) is derived for each fraction, using the same effective diffusion coefficient in vadose soils and partitioning factor. Equations

B-15 and B-16 were adapted from ASTM RBCA (1995). Default values are provided in Table B-2.

$$VF_{samb,i}\left[\frac{mg/m^3-air}{mg/kg-soil}\right]=\frac{PF_{s-v,i}}{1+\frac{U_{air}\delta_{air}L_s}{D_{s,i}^{eff}W}}\times 10^3\left[\frac{cm^3-kg}{m^3-g}\right]$$

(Equation B-15)

where:

$PF_{s-v,i}$ = Soil/Vapor phase partitioning factor for i^{th} TPH fraction [unitless]
U_{air} = Wind speed above ground surface in ambient mixing zone [cm/s]
δ_{air} = Ambient air mixing zone height [cm]
L_s = Depth to subsurface soil sources [cm]
$D_{s,i}^{eff}$ = Effective diffusion coefficient in soil for i^{th} TPH fraction [cm²/s]
W = Width of source area parallel to wind direction [cm]

VF$_{samb}$ is then combined with the allowable concentration of contaminant in the air space (RBSL$_{air}$) to determine the maximum allowable concentration of contaminant in the subsurface soil for each fraction. This concentration, RBSL$_{svout}$, is defined by Equation B-16.

$$RBSL_{svout,i}=\frac{RBSL_{air,i}\left[\frac{mg}{m^e-air}\right]}{VF_{samb,i}}$$

(Equation B-16)

Direct Contact Pathway

For direct exposure routes to soil such as ingestion, dermal absorption and inhalation of particulates, exposure is not limited by C$_{sat}$. The assumption is made that intake will continue to increase linearly with soil loading beyond C$_{sat}$. For the direct contact pathways, the Equations B-17 and B-18 are solved (adapted from TPHCWG, 1999 and ASTM, 1995, respectively).

$$HI=\sum_{i=1}^{i=n}HQ_i=\sum_{i=1}^{i=n}\frac{f_iC_{TPH}}{RBSL_i}\le 1$$

(Equation B-17)

$$RBSL_{ss,i}\left[\frac{ug}{kg\text{-}soil}\right] = \frac{THQ \times BW \times AT_n \times 365^{days}\!/_{yr}}{EF \times ED \times \left[\dfrac{10^{-6}\,{}^{kg}\!/_{mg} \times (IR_{soil} \times RAF_{o,i} \times SA \times M \times RAF_{d,i})}{RfD_{o,i}}\right] + \left[\dfrac{IR_{air} \times (VF_{ss,i} + VF_{p,i})}{RfD_{i,i}}\right]}$$

<div align="right">(Equation B-18)</div>

where:

THQ	=	Target hazard quotient for constituent [unitless]
BW	=	Body weight [kg]
AT_n	=	Averaging time for noncarcinogens [years]
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration [years]
IR_{soil}	=	Soil ingestion rate [mg/day]
$RAF_{o,i}$	=	Relative oral absorption factor for i^{th} TPH fraction [unitless]
SA	=	Skin surface area [cm^2/day]
M	=	Soil to skin adherence factor [mg/cm^2]
$RAF_{d,i}$	=	Relative dermal absorption factor for i^{th} TPH fraction [unitless]
$RfD_{o,i}$	=	Oral chronic reference dose for i^{th} TPH fraction [mg/kg-day]
IR_{air}	=	Inhalation rate [m^3/day]
$VF_{ss,i}$	=	Surficial soils to ambient air partition factor (vapor) for i^{th} TPH fraction [unitless]
$VF_{p,i}$	=	Surficial soils to ambient air partition factor (particulates) for i^{th} TPH fraction [unitless]
$RfD_{i,i}$	=	Inhalation chronic reference dose for i^{th} TPH fraction [mg/kg-day]

Similar to the HI calculation, the RBSL equation is solved iteratively to find C_{TPH} such that HI is under the constraint of a target hazard index of 1.0. Default exposure parameters are provided in Table B-1. The fraction specific RfDs are provided in Table 3-2.

REFERENCES

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TPHCWG. 1999. A Risk-based Approach for the Management of Total Petroleum Hydrocarbons in Soil, Volume 5. Human Health Risk-based Evaluation of Petroleum Release Sites: Implementing the Working Group Approach.

APPENDIX C

RBSL MODEL RUNS

Tier 1 Model Runs

Tier 1 RBCA Model Runs

CONSTRUCTION WORKER SCENARIO

Tier 1 - 1

	Csat (mg/kg)	RBSL.R.11 s lch (mg/kg) HQ=1	RBSL.R.16 s v in (mg/kg) HQ=1	RBSL.R.16 ss (mg/kg) HQ=1	RBSL.R.18 s v out (mg/kg) HQ=1
5-6 Aliphatics	4.8E+02	8.2E+04	5.7E-01	4.9E+05	3.8E+03
5-7 Aromatics	1.6E+03	2.3E+02	1.4E-01	1.7E+04	9.1E+02
>6-8 Aliphatics	2.6E+02	3.0E+05	1.4E+02	4.9E+05	9.2E+03
>7-8 Aromatics	1.3E+03	6.1E+02	3.1E+01	1.7E+04	2.1E+03
>8-10 Aliphatics	1.4E+02	4.1E+04	3.5E+01	1.1E+04	2.4E+03
>8-10 Aromatics	1.0E+03	7.9E+02	4.8E+01	4.1E+03	3.2E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	1.7E+02	1.1E+04	1.1E+04
>10-12 Aromatics	6.3E+02	1.2E+03	2.6E+02	4.1E+03	1.8E+04
>12-16 Aliphatics	3.8E+01	6.2E+06	8.2E+02	1.1E+04	5.5E+04
>12-16 Aromatics	2.9E+02	2.5E+03	1.4E+03	4.2E+03	9.1E+04
>16-21 Aliphatics	1.3E+01	2.5E+10	9.2E+04	2.1E+05	6.1E+06
>16-21 Aromatics	8.1E+01	5.9E+03	1.2E+04	3.3E+03	7.8E+05
>21-35 Aromatics	8.3E+00	4.7E+04	1.6E+06	3.4E+03	1.1E+08
Total	1.0E+00				

	Fraction (mg/kg/mg/kg)	HQ(Ci) s lch	HQ(Ci) s v in	HQ(Ci) ss	HQ(Ci) s v out
5-6 Aliphatics	2.7E-04	7.7E-05	1.4E-03	3.9E-06	1.2E-01
5-7 Aromatics	8.0E-06	8.3E-04	1.8E-04	3.3E-06	2.9E-01
>6-8 Aliphatics	2.7E-04	2.1E-05	6.0E-04	3.9E-06	2.8E-02
>7-8 Aromatics	8.0E-06	3.1E-04	8.1E-05	3.3E-06	1.3E-01
>8-10 Aliphatics	3.6E-02	3.5E-03	3.2E-01	2.4E-02	6.0E-02
>8-10 Aromatics	1.2E-02	3.6E-01	7.8E-02	2.1E-02	3.2E-01
>10-12 Aliphatics	5.9E-01	2.7E-04	5.0E-01	3.9E-01	7.5E-03
>10-12 Aromatics	6.7E-02	5.0E-01	7.9E-02	1.2E-01	3.6E-02
>12-16 Aliphatics	2.9E-02	6.1E-06	1.1E-02	1.9E-02	7.0E-04
>12-16 Aromatics	2.9E-02	1.2E-01	6.7E-03	5.0E-02	3.2E-03
>16-21 Aliphatics	6.1E-02	5.3E-10	1.4E-04	2.1E-03	2.1E-06
>16-21 Aromatics	1.0E-01	1.4E-02	2.8E-03	2.2E-01	1.0E-04
>21-35 Aromatics	7.4E-02	1.8E-04	5.2E-06	1.6E-01	7.7E-08
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11 s lch (mg/kg)	RBSL.R.16 s v in (mg/kg)	RBSL.R.18 ss (mg/kg)	RBSL.R.16 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	2.4E+04	3.1E+02	7.2E+03	3.3E+07

COMMERCIAL SCENARIO

	Csat (mg/kg)	1.1E+01 s lch (mg/kg) Non-Carc	1.6E+01 s v in (mg/kg) Non-Carc	1.8E+01 ss (mg/kg) Non-Carc	1.6E+01 s v out (mg/kg) Non-Carc
5-6 Aliphatics	4.8E+02	8.2E+04	1.4E+02	5.2E+05	3.8E+03
5-7 Aromatics	1.6E+03	2.3E+02	3.3E+01	1.8E+04	9.1E+02
>6-8 Aliphatics	2.6E+02	3.0E+05	3.4E+02	5.2E+05	9.2E+03
>7-8 Aromatics	1.3E+03	6.1E+02	7.5E+01	1.8E+04	2.1E+03
>8-10 Aliphatics	1.4E+02	4.1E+04	8.7E+01	1.2E+04	2.4E+03
>8-10 Aromatics	1.0E+03	7.9E+02	1.2E+02	4.3E+03	3.2E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	4.2E+02	1.2E+04	1.1E+04
>10-12 Aromatics	6.3E+02	1.2E+03	6.5E+02	4.3E+03	1.8E+04
>12-16 Aliphatics	3.8E+01	6.2E+06	2.0E+03	1.2E+04	5.5E+04
>12-16 Aromatics	2.9E+02	2.5E+03	3.4E+03	4.4E+03	9.1E+04
>16-21 Aliphatics	1.3E+01	2.5E+10	2.3E+05	2.2E+05	6.1E+06
>16-21 Aromatics	8.1E+01	5.9E+03	2.9E+04	3.5E+03	7.8E+05
>21-35 Aromatics	8.3E+00	4.7E+04	4.0E+06	3.6E+03	1.1E+08
Total	1.0E+00				

	Fraction (mg/kg/mg/kg)	HQ(Ci) s lch	HQ(Ci) s v in	HQ(Ci) ss	HQ(Ci) s v out
5-6 Aliphatics	2.7E-04	7.7E-05	2.3E-03	3.9E-06	1.2E-01
5-7 Aromatics	8.0E-06	8.3E-04	2.9E-04	3.3E-06	2.9E-01
>6-8 Aliphatics	2.7E-04	2.1E-05	9.6E-04	3.9E-06	2.8E-02
>7-8 Aromatics	8.0E-06	3.1E-04	1.3E-04	3.3E-06	1.3E-01
>8-10 Aliphatics	3.6E-02	3.5E-03	5.1E-01	2.4E-02	6.0E-02
>8-10 Aromatics	1.2E-02	3.6E-01	1.2E-01	2.1E-02	3.2E-01
>10-12 Aliphatics	5.9E-01	2.7E-04	2.0E-01	3.9E-01	7.5E-03
>10-12 Aromatics	6.7E-02	5.0E-01	1.3E-01	1.2E-01	3.6E-02
>12-16 Aliphatics	2.9E-02	6.1E-06	1.8E-02	1.9E-02	7.0E-04
>12-16 Aromatics	2.9E-02	1.2E-01	1.1E-02	5.0E-02	3.2E-03
>16-21 Aliphatics	6.1E-02	5.3E-10	5.8E-05	2.1E-03	2.1E-06
>16-21 Aromatics	1.0E-01	1.4E-02	2.8E-03	2.2E-01	1.0E-04
>21-35 Aromatics	7.4E-02	1.8E-04	2.1E-01	1.6E-01	7.7E-08
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	1.1E+01 s lch (mg/kg)	1.6E+01 s v in (mg/kg)	1.8E+01 ss (mg/kg)	1.6E+01 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	2.4E+04	1.2E+02	7.6E+03	3.3E+07

Tier 1 RBCA Model Runs

Tier 1-2

CONSTRUCTION WORKER SCENARIO

	Csat (mg/kg)	RBSL.R.11 s lch (mg/kg) HQ=1	RBSL.R.16 s v in (mg/kg) HQ=1	RBSL.R.18 ss (mg/kg) HQ=1	RBSL.R.16 s v out (mg/kg) HQ=1
5-6 Aliphatics	4.8E+02	8.2E+04	5.7E+01	4.9E+05	3.8E+03
5-7 Aromatics	1.6E+03	2.3E+02	1.4E+01	1.7E+04	9.1E+02
>6-8 Aliphatics	2.6E+02	3.0E+05	1.4E+02	4.9E+05	9.2E+03
>7-8 Aromatics	1.3E+03	6.1E+02	3.1E+01	1.7E+04	2.1E+03
>8-10 Aliphatics	1.4E+02	4.1E+04	3.5E+01	1.1E+04	2.4E+03
>8-10 Aromatics	1.0E+03	7.9E+02	4.8E+01	4.1E+03	3.2E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	1.7E+02	1.1E+04	1.1E+04
>10-12 Aromatics	6.3E+02	1.2E+03	2.6E+02	4.1E+03	1.8E+04
>12-16 Aliphatics	3.8E+01	6.2E+06	8.2E+02	1.1E+04	5.5E+04
>12-16 Aromatics	2.9E+02	2.5E+03	1.4E+03	4.2E+03	9.1E+04
>16-21 Aliphatics	1.3E+01	2.5E+10	9.2E+04	2.1E+05	6.1E+06
>16-21 Aromatics	8.1E+01	5.9E+03	1.2E+04	3.3E+03	7.8E+05
>21-35 Aromatics	8.3E+00	4.7E+04	1.6E+06	3.4E+03	1.1E+08

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	5.3E-04	8.9E-05	2.8E-03	5.9E-06	1.2E-01
5-7 Aromatics	1.4E-05	8.3E-04	3.0E-04	4.4E-06	2.9E-01
>6-8 Aliphatics	3.6E-03	1.7E-04	7.8E-03	4.0E-05	2.8E-02
>7-8 Aromatics	1.4E-05	3.1E-04	1.3E-04	4.4E-06	1.3E-01
>8-10 Aliphatics	2.1E-02	3.5E-03	1.7E-02	1.0E-02	6.0E-02
>8-10 Aromatics	2.1E-02	3.6E-01	1.3E-01	2.8E-02	3.2E-01
>10-12 Aliphatics	3.5E-01	2.7E-04	5.0E-01	1.8E-01	7.5E-03
>10-12 Aromatics	1.3E-01	5.0E-01	1.5E-01	1.8E-01	3.6E-02
>12-16 Aliphatics	5.3E-02	6.1E-06	1.9E-02	2.7E-02	7.0E-04
>12-16 Aromatics	5.3E-02	1.2E-01	1.2E-02	6.9E-02	3.2E-03
>16-21 Aliphatics	5.3E-02	5.3E-10	1.4E-04	1.4E-03	2.1E-06
>16-21 Aromatics	1.8E-01	1.4E-02	4.7E-03	3.0E-01	1.0E-04
>21-35 Aromatics	1.3E-01	1.8E-04	5.2E-06	2.1E-01	7.7E-08
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11 s lch (mg/kg)	RBSL.R.16 s v in (mg/kg)	RBSL.R.18 ss (mg/kg)	RBSL.R.16 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	1.4E+04	3.0E+02	5.5E+03	1.9E+07

COMMERCIAL SCENARIO

	Csat (mg/kg)	1.1E+01 s lch (mg/kg) Non-Carc	1.6E+01 s v in (mg/kg) Non-Carc	1.8E+01 ss (mg/kg) Non-Carc	1.6E+01 s v out (mg/kg) Non-Carc
5-6 Aliphatics	4.8E+02	8.2E+04	1.4E+02	5.2E+05	3.8E+03
5-7 Aromatics	1.6E+03	2.3E+02	3.3E+01	1.8E+04	9.1E+02
>6-8 Aliphatics	2.6E+02	3.0E+05	3.4E+02	5.2E+05	9.2E+03
>7-8 Aromatics	1.3E+03	6.1E+02	7.5E+01	1.8E+04	2.1E+03
>8-10 Aliphatics	1.4E+02	4.1E+04	8.7E+01	1.2E+04	2.4E+03
>8-10 Aromatics	1.0E+03	7.9E+02	1.2E+02	4.3E+03	3.2E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	4.2E+02	1.2E+04	1.1E+04
>10-12 Aromatics	6.3E+02	1.2E+03	6.5E+02	4.3E+03	1.8E+04
>12-16 Aliphatics	3.8E+01	6.2E+06	2.0E+03	1.2E+04	5.5E+04
>12-16 Aromatics	2.9E+02	2.5E+03	3.4E+03	4.4E+03	9.1E+04
>16-21 Aliphatics	1.3E+01	2.5E+10	2.3E+05	2.2E+05	6.1E+06
>16-21 Aromatics	8.1E+01	5.9E+03	2.9E+04	3.5E+03	7.8E+05
>21-35 Aromatics	8.3E+00	4.7E+04	4.0E+06	3.6E+03	1.1E+08

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	5.3E-04	8.9E-05	4.5E-03	5.9E-06	1.2E-01
5-7 Aromatics	1.4E-05	8.3E-04	4.9E-04	4.4E-06	2.9E-01
>6-8 Aliphatics	3.6E-03	1.7E-04	1.3E-02	4.0E-05	2.8E-02
>7-8 Aromatics	1.4E-05	3.1E-04	2.2E-04	4.4E-06	1.3E-01
>8-10 Aliphatics	2.1E-02	3.5E-03	2.9E-01	1.0E-02	6.0E-02
>8-10 Aromatics	2.1E-02	3.6E-01	2.1E-01	2.8E-02	3.2E-01
>10-12 Aliphatics	3.5E-01	2.7E-04	2.0E-01	1.8E-01	7.5E-03
>10-12 Aromatics	1.3E-01	5.0E-01	2.4E-01	1.8E-01	3.6E-02
>12-16 Aliphatics	5.3E-02	6.1E-06	1.9E-02	2.7E-02	7.0E-04
>12-16 Aromatics	5.3E-02	1.2E-01	1.9E-02	6.9E-02	3.2E-03
>16-21 Aliphatics	5.3E-02	5.3E-10	5.8E-05	1.4E-03	2.1E-06
>16-21 Aromatics	1.8E-01	1.4E-02	2.8E-03	3.0E-01	1.0E-04
>21-35 Aromatics	1.3E-01	1.8E-04	2.1E-06	2.1E-01	7.7E-08
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	1.1E+01 s lch (mg/kg)	1.6E+01 s v in (mg/kg)	1.8E+01 ss (mg/kg)	1.6E+01 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	1.4E+04	1.2E+02	5.8E+03	1.9E+07

Tier 1 RBCA Model Runs

Tier 1 - 4 — CONSTRUCTION WORKER SCENARIO

	Csat (mg/kg)	RBSL.R.11 s lch (mg/kg) HQ=1	RBSL.R.16 s v in (mg/kg) HQ=1	RBSL.R.16 ss (mg/kg) HQ=1	RBSL.R.18 s v out (mg/kg) HQ=1
5-6 Aliphatics	4.8E+02	8.2E+04	5.7E+01	4.9E+05	3.8E+03
5-7 Aromatics	1.6E+03	2.3E+02	1.4E+01	1.7E+04	9.1E+02
>6-8 Aliphatics	2.6E+02	3.0E+05	1.4E+02	4.9E+05	9.2E+03
>7-8 Aromatics	1.3E+03	6.1E+02	3.1E+01	1.7E+04	2.1E+03
>8-10 Aliphatics	1.4E+02	4.1E+04	3.5E+01	1.1E+04	2.4E+03
>8-10 Aromatics	1.0E+03	7.9E+02	4.8E+01	4.1E+03	3.2E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	1.7E+02	1.1E+04	1.1E+04
>10-12 Aromatics	6.3E+02	1.2E+03	2.6E+02	4.1E+03	1.8E+04
>12-16 Aliphatics	3.8E+01	6.2E+06	8.2E+02	1.1E+04	5.5E+04
>12-16 Aromatics	2.9E+02	2.5E+03	1.4E+03	4.2E+03	9.1E+04
>16-21 Aliphatics	1.3E+01	2.5E+10	9.2E+04	2.1E+05	6.1E+06
>16-21 Aromatics	8.1E+01	5.9E+03	1.2E+04	3.3E+03	7.8E+05
>21-35 Aromatics	8.3E+00	4.7E+04	1.6E+06	3.4E+03	1.1E+08

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	6.0E-03	6.8E-04	8.1E-03	9.9E-05	1.2E-01
5-7 Aromatics	1.4E-04	5.5E-03	7.7E-04	6.4E-05	2.9E-01
>6-8 Aliphatics	6.0E-03	1.9E-04	3.3E-03	9.9E-05	2.8E-02
>7-8 Aromatics	1.4E-04	2.1E-03	3.4E-04	6.4E-05	1.3E-01
>8-10 Aliphatics	3.2E-01	3.5E-03	7.0E-01	2.4E-01	6.0E-02
>8-10 Aromatics	3.6E-02	4.2E-01	5.7E-02	7.1E-02	3.2E-01
>10-12 Aliphatics	4.6E-01	2.7E-04	2.0E-01	3.4E-01	7.5E-03
>10-12 Aromatics	8.7E-02	5.0E-01	2.5E-02	1.7E-01	3.6E-02
>12-16 Aliphatics	1.5E-02	6.1E-06	1.4E-03	1.1E-02	7.0E-04
>12-16 Aromatics	1.4E-02	5.4E-02	8.1E-04	2.8E-02	3.2E-03
>16-21 Aliphatics	3.1E-03	5.3E-10	2.6E-06	1.2E-04	2.1E-06
>16-21 Aromatics	1.9E-02	1.4E-02	1.2E-04	4.6E-02	1.0E-04
>21-35 Aromatics	3.7E-02	1.8E-04	1.8E-06	8.8E-02	7.7E-08
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11 s lch (mg/kg)	RBSL.R.16 s v in (mg/kg)	RBSL.R.16 ss (mg/kg)	RBSL.R.18 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	9.2E+03	7.7E+01	8.1E+03	1.9E+06

COMMERCIAL SCENARIO

	Csat (mg/kg)	s lch 1.1E+01 (mg/kg) Non-Carc	s v in 1.6E+01 (mg/kg) Non-Carc	ss 1.8E+01 (mg/kg) Non-Carc	s v out 1.6E+01 (mg/kg) Non-Carc
5-6 Aliphatics	4.8E+02	8.2E+04	1.4E+02	5.2E+05	3.8E+03
5-7 Aromatics	1.6E+03	2.3E+02	3.3E+01	1.8E+04	9.1E+02
>6-8 Aliphatics	2.6E+02	3.0E+05	3.4E+02	5.2E+05	9.2E+03
>7-8 Aromatics	1.3E+03	6.1E+02	7.5E+01	1.8E+04	2.1E+03
>8-10 Aliphatics	1.4E+02	4.1E+04	8.7E+01	1.2E+04	2.4E+03
>8-10 Aromatics	1.0E+03	7.9E+02	1.2E+02	4.3E+03	3.2E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	4.2E+02	1.2E+04	1.1E+04
>10-12 Aromatics	6.3E+02	1.2E+03	6.5E+02	4.3E+03	1.8E+04
>12-16 Aliphatics	3.8E+01	6.2E+06	2.0E+03	1.2E+04	5.5E+04
>12-16 Aromatics	2.9E+02	2.5E+03	3.4E+03	4.4E+03	9.1E+04
>16-21 Aliphatics	1.3E+01	2.5E+10	2.3E+05	2.2E+05	6.1E+06
>16-21 Aromatics	8.1E+01	5.9E+03	2.9E+04	3.5E+03	7.8E+05
>21-35 Aromatics	8.3E+00	4.7E+04	4.0E+06	3.6E+03	1.1E+08

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	6.0E-03	6.8E-04	8.1E-03	9.9E-05	1.2E-01
5-7 Aromatics	1.4E-04	5.5E-03	7.7E-04	6.5E-05	2.9E-01
>6-8 Aliphatics	6.0E-03	1.9E-04	3.3E-03	9.9E-05	2.8E-02
>7-8 Aromatics	1.4E-04	2.1E-03	3.4E-04	6.5E-05	1.3E-01
>8-10 Aliphatics	3.2E-01	3.5E-03	7.0E-01	2.4E-01	6.0E-02
>8-10 Aromatics	3.6E-02	4.2E-01	5.7E-02	7.2E-02	3.2E-01
>10-12 Aliphatics	4.6E-01	2.7E-04	2.0E-01	3.4E-01	7.5E-03
>10-12 Aromatics	8.7E-02	5.0E-01	2.5E-02	1.7E-01	3.6E-02
>12-16 Aliphatics	1.5E-02	6.1E-06	1.4E-03	1.1E-02	7.0E-04
>12-16 Aromatics	1.4E-02	5.4E-02	8.1E-04	2.8E-02	3.2E-03
>16-21 Aliphatics	3.1E-03	5.3E-10	2.6E-06	1.2E-04	2.1E-06
>16-21 Aromatics	1.9E-02	1.4E-02	1.2E-04	4.6E-02	1.0E-04
>21-35 Aromatics	3.7E-02	1.8E-04	1.8E-06	8.8E-02	7.7E-08
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	s lch 1.1E+01 (mg/kg)	s v in 1.6E+01 (mg/kg)	ss 1.8E+01 (mg/kg)	s v out 1.6E+01 (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	9.2E+03	1.9E+02	8.6E+03	1.9E+06

Tier 1 RBCA Model Runs

CONSTRUCTION WORKER SCENARIO

Tier 1 - 6	Csat (mg/kg)	RBSL.R.11 s lch (mg/kg) HQ=1	RBSL.R.16 s v in (mg/kg) HQ=1	RBSL.R.16 ss (mg/kg) HQ=1	RBSL.R.18 s v out (mg/kg) HQ=1
5-6 Aliphatics	4.8E+02	8.2E+04	5.7E+01	4.9E+05	3.8E+03
5-7 Aromatics	1.6E+03	2.3E+02	1.4E+01	1.7E+04	9.1E+02
>6-8 Aliphatics	2.6E+02	3.0E+05	1.4E+02	4.9E+05	9.2E+03
>7-8 Aromatics	1.3E+03	6.1E+02	3.1E+01	1.7E+04	2.1E+03
>8-10 Aliphatics	1.4E+02	4.1E+04	3.5E+01	1.1E+04	2.4E+03
>8-10 Aromatics	1.0E+03	7.9E+02	4.8E+01	4.1E+03	3.2E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	1.7E+02	1.1E+04	1.1E+04
>10-12 Aromatics	6.3E+02	1.2E+03	2.6E+02	4.1E+03	1.8E+04
>12-16 Aliphatics	3.8E+01	6.2E+06	8.2E+02	1.1E+04	5.5E+04
>12-16 Aromatics	2.9E+02	2.5E+03	1.4E+03	4.2E+03	9.1E+04
>16-21 Aliphatics	1.3E+01	2.5E+10	9.2E+04	2.1E+05	6.1E+06
>16-21 Aromatics	8.1E+01	5.9E+03	1.2E+04	3.3E+03	7.8E+05
>21-35 Aromatics	8.3E+00	4.7E+04	1.6E+06	3.4E+03	1.1E+08

	Fraction mg/kg/mg/kg	HQ(Cl)	HQ(Cl)	HQ(Cl)	HQ(Cl)
5-6 Aliphatics	1.2E-03	1.4E-04	1.7E-03	2.1E-05	1.2E-01
5-7 Aromatics	3.3E-05	1.4E-03	1.9E-04	1.6E-05	1.7E-01
>6-8 Aliphatics	1.2E-03	4.0E-05	7.0E-04	2.1E-05	2.8E-02
>7-8 Aromatics	1.0E-04	1.7E-03	2.7E-04	5.0E-05	2.4E-01
>8-10 Aliphatics	3.0E-01	3.5E-03	6.8E-01	2.3E-01	6.0E-02
>8-10 Aromatics	3.5E-02	4.4E-01	5.8E-02	7.3E-02	3.2E-01
>10-12 Aliphatics	4.9E-01	2.7E-04	2.3E-01	3.8E-01	7.5E-03
>10-12 Aromatics	1.0E-01	5.0E-01	3.1E-02	2.2E-01	3.6E-02
>12-16 Aliphatics	2.6E-02	6.1E-06	2.5E-03	2.0E-02	7.0E-04
>12-16 Aromatics	1.0E-02	4.0E-02	5.9E-04	2.0E-02	3.2E-03
>16-21 Aliphatics	6.2E-03	5.3E-10	5.3E-06	2.5E-04	2.1E-06
>16-21 Aromatics	6.8E-03	1.1E-02	4.7E-05	1.7E-02	1.0E-04
>21-35 Aromatics	1.5E-02	1.8E-04	7.6E-07	3.8E-02	7.7E-08
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11 s lch (mg/kg)	RBSL.R.16 s v in (mg/kg)	RBSL.R.18 ss (mg/kg)	RBSL.R.16 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	9.8E+03	7.9E+01	8.4E+03	4.8E+06

COMMERCIAL SCENARIO

	Csat (mg/kg)	1.1E+01 s lch (mg/kg) Non-Carc	1.6E+01 s v in (mg/kg) Non-Carc	1.8E+01 ss (mg/kg) Non-Carc	1.6E+01 s v out (mg/kg) Non-Carc
5-6 Aliphatics	4.8E+02	8.2E+04	1.4E+02	5.2E+05	3.8E+03
5-7 Aromatics	1.6E+03	2.3E+02	3.3E+01	1.8E+04	9.1E+02
>6-8 Aliphatics	2.6E+02	3.0E+05	3.4E+02	5.2E+05	9.2E+03
>7-8 Aromatics	1.3E+03	6.1E+02	7.5E+01	1.8E+04	2.1E+03
>8-10 Aliphatics	1.4E+02	4.1E+04	8.7E+01	1.2E+04	2.4E+03
>8-10 Aromatics	1.0E+03	7.9E+02	1.2E+02	4.3E+03	3.2E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	4.2E+02	1.2E+04	1.1E+04
>10-12 Aromatics	6.3E+02	1.2E+03	6.5E+02	4.3E+03	1.8E+04
>12-16 Aliphatics	3.8E+01	6.2E+06	2.0E+03	1.2E+04	5.5E+04
>12-16 Aromatics	2.9E+02	2.5E+03	3.4E+03	4.4E+03	9.1E+04
>16-21 Aliphatics	1.3E+01	2.5E+10	2.3E+05	2.2E+05	6.1E+06
>16-21 Aromatics	8.1E+01	5.9E+03	2.9E+04	3.5E+03	7.8E+05
>21-35 Aromatics	8.3E+00	4.7E+04	4.0E+06	3.6E+03	1.1E+08

	Fraction (mg/kg/mg/kg)	HQ(Cl)	HQ(Cl)	HQ(Cl)	HQ(Cl)
5-6 Aliphatics	1.2E-03	1.4E-04	1.7E-03	2.1E-05	1.2E-01
5-7 Aromatics	3.3E-05	1.4E-03	2.0E-04	1.6E-05	1.7E-01
>6-8 Aliphatics	1.2E-03	4.0E-05	7.2E-04	2.1E-05	2.8E-02
>7-8 Aromatics	1.0E-04	1.7E-03	2.8E-04	5.1E-05	2.4E-01
>8-10 Aliphatics	3.0E-01	3.5E-03	7.0E-01	2.3E-01	6.0E-02
>8-10 Aromatics	3.5E-02	4.4E-01	6.0E-02	7.3E-02	3.2E-01
>10-12 Aliphatics	4.9E-01	2.7E-04	2.0E-01	3.8E-01	7.5E-03
>10-12 Aromatics	1.0E-01	5.0E-01	3.2E-02	2.2E-01	3.6E-02
>12-16 Aliphatics	2.6E-02	6.1E-06	2.6E-03	2.0E-02	7.0E-04
>12-16 Aromatics	1.0E-02	4.0E-02	6.1E-04	2.0E-02	3.2E-03
>16-21 Aliphatics	6.2E-03	5.3E-10	5.5E-06	2.5E-04	2.1E-06
>16-21 Aromatics	6.8E-03	1.1E-02	4.8E-05	1.7E-02	1.0E-04
>21-35 Aromatics	1.5E-02	1.8E-04	7.8E-07	3.8E-02	7.7E-08
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	1.1E+01 s lch (mg/kg)	1.6E+01 s v in (mg/kg)	1.8E+01 ss (mg/kg)	1.6E+01 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	9.8E+03	2.0E+02	8.9E+03	4.8E+06

Tier 1 RBCA Model Runs

Tier 1 - 7 CONSTRUCTION WORKER SCENARIO

	Csat (mg/kg)	RBSL.R.11 s lch (mg/kg) HQ=1	RBSL.R.16 s v out (mg/kg) HQ=1	RBSL.R.16 s v in (mg/kg) HQ=1	RBSL.R.18 ss (mg/kg) HQ=1
5-6 Aliphatics	4.8E+02	8.2E+04	3.8E+03	1.9E+03	4.9E+05
5-7 Aromatics	1.6E+03	2.3E+02	9.1E+02	6.4E+02	1.7E+04
>6-8 Aliphatics	2.6E+02	3.0E+05	9.2E+03	6.0E+03	4.9E+05
>7-8 Aromatics	1.3E+03	6.1E+02	2.1E+03	1.5E+03	1.7E+04
>8-10 Aliphatics	1.4E+02	4.1E+04	2.4E+03	1.8E+03	1.1E+04
>8-10 Aromatics	1.0E+03	7.9E+02	3.2E+03	2.4E+03	4.1E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	1.1E+04	8.8E+03	1.1E+04
>10-12 Aromatics	6.3E-02	1.2E+03	1.8E+04	1.3E+04	4.1E+03
>12-16 Aliphatics	3.8E+01	6.2E+06	5.5E+04	4.2E+04	1.1E+04
>12-16 Aromatics	2.9E+02	2.5E+03	9.1E+04	5.9E+04	4.2E+03
>16-21 Aliphatics	1.3E+01	2.5E+10	6.1E+06	4.7E+06	2.1E+05
>16-21 Aromatics	8.1E+01	5.9E+03	7.8E+05	3.3E+05	3.3E+03
>21-35 Aromatics	8.3E+00	4.7E+04	1.1E+08	6.7E+06	3.4E+03

	Fraction (mg/kg/mg/kg)	RBSL.R.11 s lch HQ(Ci)	RBSL.R.16 s v out HQ(Ci)	RBSL.R.16 s v in HQ(Ci)	RBSL.R.18 ss HQ(Ci)
5-6 Aliphatics	6.9E-03	6.6E-04	1.2E-01	1.6E-01	1.2E-04
5-7 Aromatics	1.6E-04	5.4E-03	2.9E-01	1.6E-01	7.6E-05
>6-8 Aliphatics	6.9E-03	1.8E-04	2.8E-02	3.6E-02	1.2E-04
>7-8 Aromatics	1.6E-04	2.0E-03	1.3E-01	6.9E-02	7.6E-05
>8-10 Aliphatics	4.1E-01	3.5E-03	6.0E-02	7.8E-02	3.2E-01
>8-10 Aromatics	4.8E-02	4.7E-01	3.2E-01	4.3E-01	9.9E-02
>10-12 Aliphatics	3.5E-01	2.7E-04	7.5E-03	9.7E-03	2.7E-01
>10-12 Aromatics	7.4E-02	4.6E-01	3.6E-02	5.0E-02	1.5E-01
>12-16 Aliphatics	3.7E-02	6.1E-06	7.0E-04	9.0E-04	2.8E-02
>12-16 Aromatics	1.4E-02	4.3E-02	3.2E-03	4.9E-03	2.8E-02
>16-21 Aliphatics	6.9E-03	5.3E-10	2.1E-06	2.8E-06	2.8E-04
>16-21 Aromatics	1.2E-02	1.4E-02	1.0E-04	2.4E-04	3.1E-02
>21-35 Aromatics	3.1E-02	1.8E-04	7.7E-08	1.2E-06	7.5E-02
Total	1.0E+00				
HI		RBSL.R.11 s lch (mg/kg) 1.0E+00	RBSL.R.16 s v out (mg/kg) 1.0E+00	RBSL.R.16 s v in (mg/kg) 1.0E+00	RBSL.R.18 ss (mg/kg) 1.0E+00
RBSL(HI=1) mg/kg		7.8E+03	1.7E+06	6.5E+05	8.4E+03

COMMERCIAL SCENARIO

	Csat (mg/kg)	1.1E+01 s lch (mg/kg) Non-Carc	1.6E+01 s v out (mg/kg) Non-Carc	1.6E+01 s v in (mg/kg) Non-Carc	1.8E+01 ss (mg/kg) Non-Carc
5-6 Aliphatics	4.8E+02	8.2E+04	3.8E+03	4.7E+03	5.2E+05
5-7 Aromatics	1.6E+03	2.3E+02	9.1E+02	1.6E+03	1.8E+04
>6-8 Aliphatics	2.6E+02	3.0E+05	9.2E+03	1.5E+04	5.2E+05
>7-8 Aromatics	1.3E+03	6.1E+02	2.1E+03	3.7E+03	1.8E+04
>8-10 Aliphatics	1.4E+02	4.1E+04	2.4E+03	4.3E+03	1.2E+04
>8-10 Aromatics	1.0E+03	7.9E+02	3.2E+03	5.9E+03	4.3E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	1.1E+04	2.2E+04	1.2E+04
>10-12 Aromatics	6.3E-02	1.2E+03	1.8E+04	3.1E+04	4.3E+03
>12-16 Aliphatics	3.8E+01	6.2E+06	5.5E+04	1.0E+05	1.2E+04
>12-16 Aromatics	2.9E+02	2.5E+03	9.1E+04	1.5E+05	4.4E+03
>16-21 Aliphatics	1.3E+01	2.5E+10	6.1E+06	1.2E+07	2.2E+05
>16-21 Aromatics	8.1E+01	5.9E+03	7.8E+05	8.1E+05	3.5E+03
>21-35 Aromatics	8.3E+00	4.7E+04	1.1E+08	1.7E+07	3.6E+03

	Fraction (mg/kg/mg/kg)	s lch HQ(Ci)	s v out HQ(Ci)	s v in HQ(Ci)	ss HQ(Ci)
5-6 Aliphatics	6.9E-03	6.6E-04	1.2E-01	6.6E-02	1.2E-04
5-7 Aromatics	1.6E-04	5.4E-03	2.9E-01	4.8E-01	7.7E-05
>6-8 Aliphatics	6.9E-03	1.8E-04	2.8E-02	1.5E-02	1.2E-04
>7-8 Aromatics	1.6E-04	2.0E-03	1.3E-01	2.1E-01	7.7E-05
>8-10 Aliphatics	4.1E-01	3.5E-03	6.0E-02	3.2E-02	3.1E-01
>8-10 Aromatics	4.8E-02	4.7E-01	3.2E-01	1.7E-01	9.9E-02
>10-12 Aliphatics	3.5E-01	2.7E-04	7.5E-03	4.0E-03	2.7E-01
>10-12 Aromatics	7.4E-02	4.6E-01	3.6E-02	2.0E-02	1.5E-01
>12-16 Aliphatics	3.7E-02	6.1E-06	7.0E-04	3.7E-04	2.8E-02
>12-16 Aromatics	1.4E-02	4.3E-02	3.2E-03	2.0E-03	2.8E-02
>16-21 Aliphatics	6.9E-03	5.3E-10	2.1E-06	1.1E-06	2.8E-04
>16-21 Aromatics	1.2E-02	1.4E-02	1.0E-04	9.9E-05	3.1E-02
>21-35 Aromatics	3.1E-02	1.8E-04	7.7E-08	5.0E-07	7.4E-02
Total	1.0E+00				
HI		1.1E+01 s lch (mg/kg) 1.0E+00	1.6E+01 s v out (mg/kg) 1.0E+00	1.6E+01 s v in (mg/kg) 1.0E+00	1.8E+01 ss (mg/kg) 1.0E+00
RBSL(HI=1) mg/kg		7.8E+03	1.7E+06	4.8E+06	8.8E+03

Tier 1 RBCA Model Runs

Tier 1 - 9

CONSTRUCTION WORKER SCENARIO

	Csat (mg/kg)	RBSL.R.11 s lch (mg/kg) HQ=1	RBSL.R.16 s v in (mg/kg) HQ=1	RBSL.R.18 ss (mg/kg) HQ=1	RBSL.R.16 s v out (mg/kg) HQ=1
5-6 Aliphatics	4.8E+02	8.2E+04	5.7E+01	4.9E+05	3.8E+03
5-7 Aromatics	1.6E+03	2.3E+02	1.4E+01	1.7E+04	9.1E+02
>6-8 Aliphatics	2.6E+02	3.0E+05	1.4E+02	4.9E+05	9.2E+03
>7-8 Aromatics	1.3E+03	6.1E+02	3.1E+01	1.7E+04	2.1E+03
>8-10 Aliphatics	1.4E+02	4.1E+04	3.5E+01	1.1E+04	2.4E+03
>8-10 Aromatics	1.0E+03	7.9E+02	4.8E+01	4.1E+03	3.2E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	1.7E+02	1.1E+04	1.1E+04
>10-12 Aromatics	6.3E+02	1.2E+03	2.6E+02	4.1E+03	1.8E+04
>12-16 Aliphatics	3.8E+01	6.2E+06	8.2E+02	1.1E+04	5.5E+04
>12-16 Aromatics	2.9E+02	2.5E+03	1.4E+03	4.2E+03	9.1E+04
>16-21 Aliphatics	1.3E+01	2.5E+10	9.2E+04	2.1E+05	6.1E+06
>16-21 Aromatics	8.1E+01	5.9E+03	1.2E+04	3.3E+03	7.8E+05
>21-35 Aromatics	8.3E+00	4.7E+04	1.6E+06	3.4E+03	1.1E+08

	Fraction (mg/kg/mg/kg)	HQ(CI) RBSL.R.11 s lch	HQ(CI) RBSL.R.16 s v in	HQ(CI) RBSL.R.18 ss	HQ(CI) RBSL.R.16 s v out
5-6 Aliphatics	1.8E-03	1.4E-04	2.3E-03	2.8E-05	1.2E-01
5-7 Aromatics	4.0E-05	1.1E-03	2.2E-04	1.8E-05	1.1E-01
>6-8 Aliphatics	7.7E-03	1.6E-04	4.2E-03	1.2E-04	2.8E-02
>7-8 Aromatics	2.6E-04	2.6E-03	6.4E-04	1.2E-04	3.1E-01
>8-10 Aliphatics	3.2E-01	3.5E-03	6.9E-01	2.3E-01	6.0E-02
>8-10 Aromatics	5.6E-02	4.4E-01	8.9E-02	1.1E-01	3.2E-01
>10-12 Aliphatics	4.2E-01	2.7E-04	1.8E-01	3.0E-01	7.5E-03
>10-12 Aromatics	1.1E-01	5.0E-01	3.2E-02	2.2E-01	3.6E-02
>12-16 Aliphatics	2.1E-02	6.1E-06	1.9E-03	1.5E-02	7.0E-04
>12-16 Aromatics	1.2E-02	3.0E-02	6.6E-04	2.2E-02	3.2E-03
>16-21 Aliphatics	9.0E-03	5.3E-10	7.4E-06	3.4E-04	2.1E-06
>16-21 Aromatics	1.8E-02	1.4E-02	1.2E-04	4.3E-02	1.0E-04
>21-35 Aromatics	2.2E-02	1.8E-04	1.0E-06	5.1E-02	7.7E-08
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11 s lch (mg/kg)	RBSL.R.16 s v in (mg/kg)	RBSL.R.18 ss (mg/kg)	RBSL.R.16 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	6.2E+03	7.5E+01	7.9E+03	2.4E+06

COMMERCIAL SCENARIO

	Csat (mg/kg)	1.1E+01 s lch (mg/kg) Non-Carc	1.6E+01 s v in (mg/kg) Non-Carc	1.8E+01 ss (mg/kg) Non-Carc	1.6E+01 s v out (mg/kg) Non-Carc
5-6 Aliphatics	4.8E+02	8.2E+04	1.4E+02	5.2E+05	3.8E+03
5-7 Aromatics	1.6E+03	2.3E+02	3.3E+01	1.8E+04	9.1E+02
>6-8 Aliphatics	2.6E+02	3.0E+05	3.4E+02	5.2E+05	9.2E+03
>7-8 Aromatics	1.3E+03	6.1E+02	7.5E+01	1.8E+04	2.1E+03
>8-10 Aliphatics	1.4E+02	4.1E+02	8.7E+01	1.2E+04	2.4E+03
>8-10 Aromatics	1.0E+03	7.9E+02	1.2E+02	4.3E+03	3.2E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	4.2E+02	1.2E+05	1.1E+04
>10-12 Aromatics	6.3E+02	1.2E+03	6.5E+02	4.3E+03	1.8E+04
>12-16 Aliphatics	3.8E+01	6.2E+06	2.0E+03	1.2E+04	5.5E+04
>12-16 Aromatics	2.9E+02	2.5E+03	3.4E+03	4.4E+03	9.1E+04
>16-21 Aliphatics	1.3E+01	2.5E+10	2.3E+05	2.2E+05	6.1E+06
>16-21 Aromatics	8.1E+01	5.9E+03	2.9E+04	3.5E+03	7.8E+05
>21-35 Aromatics	8.3E+00	4.7E+04	4.0E+06	3.6E+03	1.1E+08

	Fraction (mg/kg/mg/kg)	HQ(CI) s lch	HQ(CI) s v in	HQ(CI) ss	HQ(CI) s v out
5-6 Aliphatics	1.8E-03	1.4E-04	2.3E-03	2.9E-05	1.2E-01
5-7 Aromatics	4.0E-05	1.1E-03	2.2E-04	1.9E-05	1.1E-01
>6-8 Aliphatics	7.7E-03	1.6E-04	4.2E-03	1.2E-04	2.8E-02
>7-8 Aromatics	2.6E-04	2.6E-03	6.4E-04	1.2E-04	3.1E-01
>8-10 Aliphatics	3.2E-01	3.5E-03	6.9E-01	2.3E-01	6.0E-02
>8-10 Aromatics	5.6E-02	4.4E-01	8.9E-02	1.1E-01	3.2E-01
>10-12 Aliphatics	4.2E-01	2.7E-04	1.8E-01	3.0E-01	7.5E-03
>10-12 Aromatics	1.1E-01	5.0E-01	3.2E-02	2.2E-01	3.6E-02
>12-16 Aliphatics	2.1E-02	6.1E-06	1.9E-03	1.5E-02	7.0E-04
>12-16 Aromatics	1.2E-02	3.0E-02	6.6E-04	2.2E-02	3.2E-03
>16-21 Aliphatics	9.0E-03	5.3E-10	7.4E-06	3.4E-04	2.1E-06
>16-21 Aromatics	1.8E-02	1.4E-02	1.2E-04	4.3E-02	1.0E-04
>21-35 Aromatics	2.2E-02	1.8E-04	1.0E-06	5.1E-02	7.7E-08
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	1.1E+01 s lch (mg/kg)	1.6E+01 s v in (mg/kg)	1.8E+01 ss (mg/kg)	1.6E+01 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1)	6.2E+03	1.9E+02	8.4E+03	2.4E+06

Tier 1 RBCA Model Runs

CONSTRUCTION WORKER SCENARIO

Tier 1 - 11

	Csat	RBSL.R.11 s lch	RBSL.R.16 s v in	RBSL.R.18 ss	RBSL.R.16 s v out
	(mg/kg)	(mg/kg) HQ=1	(mg/kg) HQ=1	(mg/kg) HQ=1	(mg/kg) HQ=1
5-6 Aliphatics	4.8E+02	8.2E+04	5.7E+01	4.9E+05	3.8E+03
5-7 Aromatics	1.6E+03	2.3E+02	1.4E+01	1.7E+04	9.1E+02
>6-8 Aliphatics	2.6E+02	3.0E+05	1.4E+02	4.9E+05	9.2E+03
>7-8 Aromatics	1.3E+03	6.1E+02	3.1E+01	1.7E+04	2.1E+03
>8-10 Aliphatics	1.4E+02	4.1E+04	3.5E+01	1.1E+04	2.4E+03
>8-10 Aromatics	1.0E+03	7.9E+02	4.8E+01	4.1E+03	3.2E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	1.7E+02	1.1E+04	1.1E+04
>10-12 Aromatics	6.3E+02	1.2E+03	2.6E+02	4.1E+03	1.8E+04
>12-16 Aliphatics	3.8E+01	6.2E+06	8.2E+02	1.1E+04	5.5E+04
>12-16 Aromatics	2.9E+02	2.5E+03	1.4E+03	4.2E+03	9.1E+04
>16-21 Aliphatics	1.3E+01	2.5E+10	9.2E+04	2.1E+05	6.1E+06
>16-21 Aromatics	8.1E+01	5.9E+03	1.2E+04	3.3E+03	7.8E+05
>21-35 Aromatics	8.3E+00	4.7E+04	1.6E+06	3.4E+03	1.1E+08

	Fraction (mg/kg/mg/kg)	HQ(Ci) RBSL.R.11 s lch	HQ(Ci) RBSL.R.16 s v in	HQ(Ci) RBSL.R.18 ss	HQ(Ci) RBSL.R.16 s v out
5-6 Aliphatics	5.2E-03	5.6E-04	8.0E-03	8.4E-05	1.2E-01
5-7 Aromatics	1.2E-04	4.5E-03	7.4E-04	5.3E-05	2.3E-01
>6-8 Aliphatics	5.2E-03	1.6E-04	3.3E-03	8.4E-05	2.8E-02
>7-8 Aromatics	2.2E-04	3.2E-03	6.2E-04	1.0E-04	1.9E-01
>8-10 Aliphatics	2.6E-01	3.5E-03	6.3E-01	1.9E-01	6.0E-02
>8-10 Aromatics	3.8E-02	4.2E-01	6.9E-02	7.5E-02	3.2E-01
>10-12 Aliphatics	4.9E-01	2.7E-04	2.5E-01	3.5E-01	7.5E-03
>10-12 Aromatics	1.2E-01	5.0E-01	4.0E-02	2.4E-01	3.6E-02
>12-16 Aliphatics	1.3E-02	6.1E-06	1.4E-03	9.6E-03	7.0E-04
>12-16 Aromatics	1.3E-02	4.4E-02	8.0E-04	2.4E-02	3.2E-03
>16-21 Aliphatics	1.3E-02	5.3E-10	1.2E-05	4.9E-04	2.1E-06
>16-21 Aromatics	1.4E-02	1.4E-02	1.1E-04	3.4E-02	1.0E-04
>21-35 Aromatics	3.3E-02	1.8E-04	1.8E-06	7.6E-02	7.7E-08
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11 s lch (mg/kg)	RBSL.R.16 s v in (mg/kg)	RBSL.R.18 ss (mg/kg)	RBSL.R.16 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	8.8E+03	8.7E+01	7.9E+03	1.8E+06

COMMERCIAL SCENARIO

	Csat	1.1E+01 s lch	1.6E+01 s v in	1.8E+01 ss	1.6E+01 s v out
	(mg/kg)	(mg/kg) Non-Carc	(mg/kg) Non-Carc	(mg/kg) Non-Carc	(mg/kg) Non-Carc
5-6 Aliphatics	4.8E+02	8.2E+04	1.4E+02	5.2E+05	3.8E+03
5-7 Aromatics	1.6E+03	2.3E+03	3.3E+01	1.8E+04	9.1E+02
>6-8 Aliphatics	2.6E+02	3.0E+05	3.4E+02	5.2E+05	9.2E+03
>7-8 Aromatics	1.3E+03	6.1E+02	7.5E+01	1.8E+04	2.1E+03
>8-10 Aliphatics	1.4E+02	4.1E+04	8.7E+01	1.2E+04	2.4E+03
>8-10 Aromatics	1.0E+03	7.9E+02	1.2E+02	4.3E+03	3.2E+03
>10-12 Aliphatics	8.6E+01	3.1E+05	4.2E+02	1.2E+04	1.1E+04
>10-12 Aromatics	6.3E+02	1.2E+03	6.5E+02	4.3E+03	1.8E+04
>12-16 Aliphatics	3.8E+01	6.2E+06	2.0E+03	1.2E+04	5.5E+04
>12-16 Aromatics	2.9E+02	2.5E+03	3.4E+03	4.4E+03	9.1E+04
>16-21 Aliphatics	1.3E+01	2.5E+10	2.3E+05	2.2E+05	6.1E+06
>16-21 Aromatics	8.1E+01	5.9E+03	2.9E+04	3.5E+03	7.8E+05
>21-35 Aromatics	8.3E+00	4.7E+04	4.0E+06	3.6E+03	1.1E+08

	Fraction (mg/kg/mg/kg)	HQ(Ci) 1.1E+01 s lch	HQ(Ci) 1.6E+01 s v in	HQ(Ci) 1.8E+01 ss	HQ(Ci) 1.6E+01 s v out
5-6 Aliphatics	5.2E-03	5.6E-04	8.4E-03	8.4E-05	1.2E-01
5-7 Aromatics	1.2E-04	4.5E-03	7.8E-04	5.4E-05	2.3E-01
>6-8 Aliphatics	5.2E-03	1.6E-04	3.5E-03	8.4E-05	2.8E-02
>7-8 Aromatics	2.2E-04	3.2E-03	6.5E-04	1.0E-04	1.9E-01
>8-10 Aliphatics	2.6E-01	3.5E-03	6.6E-01	1.9E-01	6.0E-02
>8-10 Aromatics	3.8E-02	4.2E-01	7.3E-02	7.5E-02	3.2E-01
>10-12 Aliphatics	4.9E-01	2.7E-04	2.0E-01	3.5E-01	7.5E-03
>10-12 Aromatics	1.2E-01	5.0E-01	4.3E-02	2.4E-01	3.6E-02
>12-16 Aliphatics	1.3E-02	6.1E-06	1.5E-03	9.6E-03	7.0E-04
>12-16 Aromatics	1.3E-02	4.4E-02	8.4E-04	2.4E-02	3.2E-03
>16-21 Aliphatics	1.3E-02	5.3E-10	1.3E-05	4.9E-04	2.1E-06
>16-21 Aromatics	1.4E-02	1.4E-02	1.1E-04	3.4E-02	1.0E-04
>21-35 Aromatics	3.3E-02	1.8E-04	1.9E-06	7.5E-02	7.7E-08
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	1.1E+01 s lch (mg/kg)	1.6E+01 s v in (mg/kg)	1.8E+01 ss (mg/kg)	1.6E+01 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	8.8E+03	2.3E+02	8.4E+03	1.8E+06

Tier 1-A Model Runs

Tier 1-A RBCA Model Runs

Tier 1a - 1 — CONSTRUCTION WORKER SCENARIO

	Csat	RBSL.R.11 s lch	RBSL.R.16 s v in	RBSL.R.18 ss	RBSL.R.16 s v out
	(mg/kg)	(mg/kg) HQ=1	(mg/kg) HQ=1	(mg/kg) HQ=1	(mg/kg) HQ=1
5-6 Aliphatics	3.1E+02	3.4E+04	1.9E+03	4.9E+05	2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	6.4E+02	2.1E+04	6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	6.0E+03	5.2E+05	6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	1.5E+03	2.2E+04	1.6E+06
>8-10 Aliphatics	1.4E+02	2.5E+04	1.8E+03	1.1E+04	1.8E+06
>8-10 Aromatics	1.0E+03	5.0E+02	2.4E+03	4.5E+03	2.5E+06
>10-12 Aliphatic	8.5E+01	2.0E+05	8.8E+03	1.1E+04	9.2E+06
>10-12 Aromatic	6.3E+02	8.0E+02	1.3E+04	4.6E+03	1.3E+07
>12-16 Aliphatic	3.8E+01	4.0E+06	4.2E+04	1.1E+04	4.4E+07
>12-16 Aromatic	2.9E+02	1.6E+03	5.9E+04	4.6E+03	6.2E+07
>16-21 Aliphatic	1.3E+01	1.6E+10	4.7E+06	2.3E+05	5.0E+09
>16-21 Aromatic	8.1E+01	3.8E+03	3.3E+05	3.4E+03	3.4E+08
>21-35 Aromatic	8.3E+00	3.0E+04	6.7E+06	3.4E+03	5.6E+09

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	2.7E-04	6.0E-05	1.6E-01	4.1E-06	1.5E-04
5-7 Aromatics	8.0E-06	4.4E-04	1.6E-01	2.9E-06	2.3E-03
>6-8 Aliphatics	2.7E-04	1.3E-05	3.6E-02	3.9E-06	3.5E-05
>7-8 Aromatics	8.0E-06	1.6E-04	6.9E-02	2.8E-06	7.9E-04
>8-10 Aliphatics	3.6E-02	5.4E-03	7.8E-02	2.4E-02	7.4E-05
>8-10 Aromatics	1.2E-02	1.8E-01	4.3E-01	2.0E-02	4.1E-04
>10-12 Aliphatic	5.9E-01	4.3E-04	9.7E-03	3.9E-01	9.3E-06
>10-12 Aromatic	6.7E-02	6.5E-01	5.0E-02	1.1E-01	4.7E-05
>12-16 Aliphatic	2.9E-02	9.6E-06	9.0E-04	1.9E-02	8.6E-07
>12-16 Aromatic	2.9E-02	1.4E-01	4.9E-03	4.8E-02	4.7E-06
>16-21 Aliphatic	6.1E-02	8.2E-10	2.8E-06	2.0E-03	2.6E-09
>16-21 Aromatic	1.0E-01	2.1E-02	2.4E-04	2.3E-01	2.4E-07
>21-35 Aromatic	7.4E-02	2.8E-04	1.2E-06	1.6E-01	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11 s lch (mg/kg)	RBSL.R.16 s v in (mg/kg)	RBSL.R.18 ss (mg/kg)	RBSL.R.16 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	3.8E-03
RBSL(HI=1) mg/k	7.7E+03	1.3E+07	7.5E+03	2.2E+08

COMMERCIAL SCENARIO

	Csat	1.1E+01 s lch	1.6E+01 s v in	1.8E+01 ss	1.6E+01 s v out
	(mg/kg)	(mg/kg) Non-Carc	(mg/kg) Non-Carc	(mg/kg) Non-Carc	(mg/kg) Non-Carc
5-6 Aliphatics	3.1E+02	3.4E+04	4.7E+03	5.1E+05	2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	1.6E+03	2.2E+04	6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	1.5E+04	5.4E+05	6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	3.7E+03	2.3E+04	1.6E+06
>8-10 Aliphatics	1.4E+02	2.5E+04	4.3E+03	1.2E+04	1.8E+06
>8-10 Aromatics	1.0E+03	5.0E+02	5.9E+03	4.8E+03	2.5E+06
>10-12 Aliphatics	8.5E+01	2.0E+05	2.2E+04	1.2E+04	9.2E+06
>10-12 Aromatics	6.3E+02	8.0E+02	3.1E+04	4.8E+03	1.3E+07
>12-16 Aliphatics	3.8E+01	4.0E+06	1.0E+05	1.2E+04	4.4E+07
>12-16 Aromatics	2.9E+02	1.6E+03	1.5E+05	4.9E+03	6.2E+07
>16-21 Aliphatics	1.3E+01	1.6E+10	1.2E+07	2.4E+05	5.0E+09
>16-21 Aromatics	8.1E+01	3.8E+03	8.1E+05	3.6E+03	3.4E+08
>21-35 Aromatics	8.3E+00	3.0E+04	1.7E+07	3.6E+03	5.6E+09

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	2.7E-04	6.0E-05	6.6E-02	4.1E-06	1.5E-04
5-7 Aromatics	8.0E-06	4.4E-04	4.8E-01	2.9E-06	2.3E-03
>6-8 Aliphatics	2.7E-04	1.3E-05	1.5E-02	3.9E-06	3.5E-05
>7-8 Aromatics	8.0E-06	1.6E-04	2.1E-01	2.8E-06	7.9E-04
>8-10 Aliphatics	3.6E-02	5.4E-03	3.2E-02	2.4E-02	7.4E-05
>8-10 Aromatics	1.2E-02	1.8E-01	1.7E-01	2.0E-02	4.1E-04
>10-12 Aliphatics	5.9E-01	4.3E-04	4.0E-03	3.9E-01	9.3E-06
>10-12 Aromatics	6.7E-02	6.5E-01	2.0E-02	1.1E-01	4.7E-05
>12-16 Aliphatics	2.9E-02	9.6E-06	3.7E-04	1.9E-02	8.6E-07
>12-16 Aromatics	2.9E-02	1.4E-01	2.0E-03	4.8E-02	4.7E-06
>16-21 Aliphatics	6.1E-02	8.2E-10	1.1E-06	2.0E-03	2.6E-09
>16-21 Aromatics	1.0E-01	2.1E-02	9.9E-05	2.3E-01	2.4E-07
>21-35 Aromatics	7.4E-02	2.8E-04	5.0E-07	1.6E-01	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	1.1E+01 s lch (mg/kg)	1.6E+01 s v in (mg/kg)	1.8E+01 ss (mg/kg)	1.6E+01 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	3.8E-03
RBSL(HI=1) mg/kg	7.7E+03	9.5E+07	8.0E+03	2.7E+08

Tier 1-A RBCA Model Runs

Tier 1a - 2

CONSTRUCTION WORKER SCENARIO

	Csat (mg/kg)	RBSL.R.11 s lch (mg/kg) HQ=1	RBSL.R.16 s v in (mg/kg) HQ=1	RBSL.R.18 ss (mg/kg) HQ=1	RBSL.R.16 s v out (mg/kg) HQ=1
5-6 Aliphatics	3.1E+02	3.4E+04	1.9E+03	4.9E+05	2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	6.4E+02	2.1E+04	6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	6.0E+03	5.2E+05	6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	1.5E+03	2.2E+04	1.6E+06
>8-10 Aliphatics	1.4E+02	2.5E+04	1.8E+03	1.1E+04	1.8E+06
>8-10 Aromatics	1.0E+03	5.0E+02	2.4E+03	4.5E+03	2.5E+06
>10-12 Aliphatic	8.5E+01	2.0E+05	8.8E+03	1.1E+04	9.2E+06
>10-12 Aromatic	6.3E+02	8.0E+02	1.3E+04	4.6E+03	1.3E+07
>12-16 Aliphatic	3.8E+01	4.0E+06	4.2E+04	1.1E+04	4.4E+07
>12-16 Aromatic	2.9E+02	1.6E+03	5.9E+04	4.6E+03	6.2E+07
>16-21 Aliphatic	1.3E+01	1.6E+10	4.7E+06	2.3E+05	5.0E+09
>16-21 Aromatic	8.1E+01	3.8E+03	3.3E+05	3.4E+03	3.4E+08
>21-35 Aromatic	8.3E+00	3.0E+04	6.7E+06	3.4E+03	5.6E+09

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	5.3E-04	6.4E-05	1.6E-01	6.2E-06	1.5E-04
5-7 Aromatics	1.4E-05	4.0E-04	1.6E-01	3.8E-06	2.3E-03
>6-8 Aliphatics	3.6E-03	9.1E-05	3.6E-02	4.0E-05	3.5E-05
>7-8 Aromatics	1.4E-05	1.5E-04	6.9E-02	3.7E-06	7.9E-04
>8-10 Aliphatics	2.1E-02	3.4E-03	7.8E-02	1.1E-02	7.4E-05
>8-10 Aromatics	2.1E-02	1.7E-01	4.3E-01	2.6E-02	4.1E-04
>10-12 Aliphatics	3.5E-01	4.3E-04	9.7E-03	1.8E-01	9.3E-06
>10-12 Aromatic	1.3E-01	6.7E-01	5.0E-02	1.7E-01	4.7E-05
>12-16 Aliphatic	5.3E-02	9.6E-06	9.0E-04	2.7E-02	8.6E-07
>12-16 Aromatic	5.3E-02	1.4E-01	4.9E-03	6.6E-02	4.7E-06
>16-21 Aliphatic	5.3E-02	8.2E-10	2.8E-06	1.3E-03	2.6E-09
>16-21 Aromatic	1.8E-01	2.1E-02	2.4E-04	3.1E-01	2.4E-07
>21-35 Aromatic	1.3E-01	2.8E-04	1.2E-06	2.2E-01	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11 s lch (mg/kg)	RBSL.R.16 s v in (mg/kg)	RBSL.R.16 ss (mg/kg)	RBSL.R.18 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/k	4.1E+03	7.4E+06	5.8E+03	1.2E+08

COMMERCIAL SCENARIO

	Csat (mg/kg)	1.1E+01 s lch Non-Carc (mg/kg)	1.6E+01 s v in Non-Carc (mg/kg)	1.8E+01 ss Non-Carc (mg/kg)	1.6E+01 s v out Non-Carc (mg/kg)
5-6 Aliphatics	3.1E+02	3.4E+04	4.7E+03	5.1E+05	2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	1.6E+03	2.2E+04	6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	1.5E+04	5.4E+05	6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	3.7E+03	2.3E+04	1.6E+06
>8-10 Aliphatics	1.4E+02	2.5E+04	4.3E+03	1.2E+04	1.8E+06
>8-10 Aromatics	1.0E+03	5.0E+02	5.9E+03	4.8E+03	2.5E+06
>10-12 Aliphatics	8.5E+01	2.0E+05	2.2E+04	1.2E+04	9.2E+06
>10-12 Aromatics	6.3E+02	8.0E+02	3.1E+04	4.8E+03	1.3E+07
>12-16 Aliphatics	3.8E+01	4.0E+06	1.0E+05	1.2E+04	4.4E+07
>12-16 Aromatics	2.9E+02	1.6E+03	1.5E+05	4.9E+03	6.2E+07
>16-21 Aliphatics	1.3E+01	1.6E+10	1.2E+07	2.4E+05	5.0E+09
>16-21 Aromatics	8.1E+01	3.8E+03	8.1E+05	3.6E+03	3.4E+08
>21-35 Aromatics	8.3E+00	3.0E+04	1.7E+07	3.6E+03	5.6E+09

	Fraction HQ(Ci) (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	5.3E-04	6.4E-05	6.6E-02	6.3E-06	1.5E-04
5-7 Aromatics	1.4E-05	4.0E-04	4.8E-01	3.8E-06	2.3E-03
>6-8 Aliphatics	3.6E-03	9.1E-05	1.5E-02	4.0E-05	3.5E-05
>7-8 Aromatics	1.4E-05	1.5E-04	2.1E-01	3.7E-06	7.9E-04
>8-10 Aliphatics	2.1E-02	3.4E-03	3.2E-02	1.1E-02	7.4E-05
>8-10 Aromatics	2.1E-02	1.7E-01	1.7E-01	2.6E-02	4.1E-04
>10-12 Aliphatics	3.5E-01	4.3E-04	4.0E-03	1.8E-01	9.3E-06
>10-12 Aromatics	1.3E-01	6.7E-01	2.0E-02	1.7E-01	4.7E-05
>12-16 Aliphatics	5.3E-02	9.6E-06	3.7E-04	2.7E-02	8.6E-07
>12-16 Aromatics	5.3E-02	1.4E-01	2.0E-03	6.6E-02	4.7E-06
>16-21 Aliphatics	5.3E-02	8.2E-10	1.1E-06	1.3E-03	2.6E-09
>16-21 Aromatics	1.8E-01	2.1E-02	9.9E-05	3.1E-01	2.4E-07
>21-35 Aromatics	1.3E-01	2.8E-04	5.0E-07	2.2E-01	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	1.1E+01 s lch (mg/kg)	1.6E+01 s v in (mg/kg)	1.8E+01 ss (mg/kg)	1.6E+01 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	4.1E+03	5.5E+07	6.1E+03	1.3E+08

Tier 1-A RBCA Model Runs

Tier 1a - 4

CONSTRUCTION WORKER SCENARIO

	Csat	RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg) HQ=1	(mg/kg) HQ=1	(mg/kg) HQ=1	(mg/kg) HQ=1
5-6 Aliphatics	3.1E+02	3.4E+04	1.9E+03	4.9E+05	2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	6.4E+02	2.1E+04	6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	6.0E+03	5.2E+05	6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	1.5E+03	2.2E+04	1.6E+06
>8-10 Aliphatics	1.4E+02	2.5E+04	1.8E+03	1.1E+04	1.8E+06
>8-10 Aromatics	1.0E+03	5.0E+02	2.4E+03	4.5E+03	2.5E+06
>10-12 Aliphatic	8.5E+01	2.0E+05	8.8E+03	1.1E+04	9.2E+06
>10-12 Aromatic	6.3E+02	8.0E+02	1.3E+04	4.6E+03	1.3E+07
>12-16 Aliphatic	3.8E+01	4.0E+06	4.2E+04	1.1E+04	4.4E+07
>12-16 Aromatic	2.9E+02	1.6E+03	5.9E+04	4.6E+03	6.2E+07
>16-21 Aliphatic	1.3E+01	1.6E+10	4.7E+06	2.3E+05	5.0E+09
>16-21 Aromatic	8.1E+01	3.8E+03	3.3E+05	3.4E+03	3.4E+08
>21-35 Aromatic	8.3E+00	3.0E+04	6.7E+06	3.4E+03	5.6E+09

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	6.0E-03	9.0E-04	1.6E-01	1.1E-04	1.5E-04
5-7 Aromatics	1.4E-04	5.0E-03	1.6E-01	5.6E-05	2.3E-03
>6-8 Aliphatics	6.0E-03	1.9E-04	3.6E-02	1.0E-04	3.5E-05
>7-8 Aromatics	1.4E-04	1.8E-03	6.9E-02	5.4E-05	7.9E-04
>8-10 Aliphatics	3.2E-01	5.4E-03	7.8E-02	2.5E-01	7.4E-05
>8-10 Aromatics	3.6E-02	3.6E-01	4.3E-01	6.8E-02	4.1E-04
>10-12 Aliphatic	4.6E-01	4.3E-04	9.7E-03	3.4E-01	9.3E-06
>10-12 Aromatic	8.7E-02	5.6E-01	5.0E-02	1.6E-01	4.7E-05
>12-16 Aliphatic	1.5E-02	9.6E-06	9.0E-04	1.1E-02	8.6E-07
>12-16 Aromatic	1.4E-02	4.6E-02	4.9E-03	2.7E-02	4.7E-06
>16-21 Aliphatic	3.1E-03	8.2E-10	2.8E-06	1.2E-04	2.6E-09
>16-21 Aromatic	1.9E-02	2.1E-02	2.4E-04	4.7E-02	2.4E-07
>21-35 Aromatic	3.7E-02	2.8E-04	1.2E-06	9.3E-02	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11	RBSL.R.16	RBSL.R.18	RBSL.R.16
	s lch (mg/kg)	s v in (mg/kg)	ss (mg/kg)	s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	3.8E-03
RBSL(HI=1) mg/kg	5.1E+03	7.5E+05	8.6E+03	1.2E+07

COMMERCIAL SCENARIO

	Csat	1.1E+01	1.6E+01	1.8E+01	1.6E+01
		s lch	s v in	ss	s v out
	(mg/kg)	(mg/kg) Non-Carc	(mg/kg) Non-Carc	(mg/kg) Non-Carc	(mg/kg) Non-Carc
5-6 Aliphatics	3.1E+02	3.4E+04	4.7E+03	5.1E+05	2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	1.6E+03	2.2E+04	6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	1.5E+04	5.4E+05	6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	3.7E+03	2.3E+04	1.6E+06
>8-10 Aliphatics	1.4E+02	2.5E+04	4.3E+03	1.2E+04	1.8E+06
>8-10 Aromatics	1.0E+03	5.0E+02	5.9E+03	4.8E+03	2.5E+06
>10-12 Aliphatics	8.5E+01	2.0E+05	2.2E+04	1.2E+04	9.2E+06
>10-12 Aromatics	6.3E+02	8.0E+02	3.1E+04	4.8E+03	1.3E+07
>12-16 Aliphatics	3.8E+01	4.0E+06	1.0E+05	1.2E+04	4.4E+07
>12-16 Aromatics	2.9E+02	1.6E+03	1.5E+05	4.9E+03	6.2E+07
>16-21 Aliphatics	1.3E+01	1.6E+10	1.2E+07	2.4E+05	5.0E+09
>16-21 Aromatics	8.1E+01	3.8E+03	8.1E+05	3.6E+03	3.4E+08
>21-35 Aromatics	8.3E+00	3.0E+04	1.7E+07	3.6E+03	5.6E+09

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	6.0E-03	9.0E-04	6.6E-02	1.1E-04	1.5E-04
5-7 Aromatics	1.4E-04	5.0E-03	4.8E-01	5.6E-05	2.3E-03
>6-8 Aliphatics	6.0E-03	1.9E-04	1.5E-02	1.0E-04	3.5E-05
>7-8 Aromatics	1.4E-04	1.8E-03	2.1E-01	5.4E-05	7.9E-04
>8-10 Aliphatics	3.2E-01	5.4E-03	3.2E-02	2.5E-01	7.4E-05
>8-10 Aromatics	3.6E-02	3.6E-01	1.7E-01	6.8E-02	4.1E-04
>10-12 Aliphatics	4.6E-01	4.3E-04	4.0E-03	3.4E-01	9.3E-06
>10-12 Aromatics	8.7E-02	5.6E-01	2.0E-02	1.6E-01	4.7E-05
>12-16 Aliphatics	1.5E-02	9.6E-06	3.7E-04	1.1E-02	8.6E-07
>12-16 Aromatics	1.4E-02	4.6E-02	2.0E-03	2.7E-02	4.7E-06
>16-21 Aliphatics	3.1E-03	8.2E-10	1.1E-06	1.2E-04	2.6E-09
>16-21 Aromatics	1.9E-02	2.1E-02	9.9E-05	4.7E-02	2.4E-07
>21-35 Aromatics	3.7E-02	2.8E-04	5.0E-07	9.3E-02	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	1.1E+01	1.6E+01	1.8E+01	1.6E+01
	s lch (mg/kg)	s v in (mg/kg)	ss (mg/kg)	s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	3.8E-03
RBSL(HI=1) mg/kg	5.1E+03	5.6E+06	9.1E+03	1.4E+07

Tier 1-A RBCA Model Runs

CONSTRUCTION WORKER SCENARIO

Tier 1a - 6

	Csat (mg/kg)	RBSL.R.11 s lch (mg/kg) HQ=1	RBSL.R.16 s v in (mg/kg) HQ=1	RBSL.R.18 ss (mg/kg) HQ=1	RBSL.R.16 s v out (mg/kg) HQ=1
5-6 Aliphatics	3.1E+02	3.4E+04	1.9E+03	4.9E+05	2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	6.4E+02	2.1E+04	6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	6.0E+03	5.2E+05	6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	1.5E+03	2.2E+04	1.6E+06
>8-10 Aliphatics	1.4E+02	2.5E+04	1.8E+03	1.1E+04	1.8E+06
>8-10 Aromatics	1.0E+03	5.0E+02	2.4E+04	4.5E+03	2.5E+06
>10-12 Aliphatic	8.5E+01	2.0E+05	8.8E+03	1.1E+04	9.2E+06
>10-12 Aromatic	6.3E+02	8.0E+02	1.3E+04	4.6E+03	1.3E+07
>12-16 Aliphatic	3.8E+01	4.0E+06	4.2E+04	1.1E+04	4.4E+07
>12-16 Aromatic	2.9E+02	1.6E+03	5.9E+04	4.6E+03	6.2E+07
>16-21 Aliphatic	1.3E+01	1.6E+10	4.7E+06	2.3E+05	5.0E+09
>16-21 Aromatic	8.1E+01	3.8E+03	3.3E+05	3.4E+03	3.4E+08
>21-35 Aromatic	8.3E+00	3.0E+04	6.7E+06	3.4E+03	5.6E+09
Total					

	Fraction HQ(Ci) (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	1.2E-03	1.7E-04	1.6E-01	2.2E-05	1.5E-04
5-7 Aromatics	3.3E-05	1.1E-03	9.8E-02	1.4E-05	2.3E-03
>6-8 Aliphatics	1.2E-03	3.6E-05	3.6E-02	2.1E-05	3.5E-05
>7-8 Aromatics	1.0E-04	1.3E-03	1.3E-01	4.3E-05	7.9E-04
>8-10 Aliphatics	3.0E-01	5.4E-03	7.8E-02	2.4E-01	7.4E-05
>8-10 Aromatics	3.5E-02	3.3E-01	4.3E-01	7.0E-02	4.1E-04
>10-12 Aliphatic	4.9E-01	4.3E-04	9.7E-03	3.9E-01	9.3E-06
>10-12 Aromatic	1.0E-01	6.2E-01	5.0E-02	2.1E-01	4.7E-05
>12-16 Aliphatic	2.6E-02	9.6E-06	9.0E-04	2.1E-02	8.6E-07
>12-16 Aromatic	1.0E-02	3.0E-02	4.9E-03	2.0E-02	4.7E-06
>16-21 Aliphatic	6.2E-03	8.2E-10	2.8E-06	2.4E-04	2.6E-09
>16-21 Aromatic	6.8E-03	8.6E-03	2.4E-04	1.8E-02	2.4E-07
>21-35 Aromatic	1.5E-02	2.8E-04	1.2E-06	4.0E-02	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11 s lch (mg/kg)	RBSL.R.16 s v in (mg/kg)	RBSL.R.18 ss (mg/kg)	RBSL.R.16 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	3.8E-03
RBSL(HI=1) mg/kg	4.7E+03	1.9E+06	9.0E+03	5.9E+07

COMMERCIAL SCENARIO

	Csat (mg/kg)	1.1E+01 s lch (mg/kg) Non-Carc	1.6E+01 s v in (mg/kg) Non-Carc	1.8E+01 ss (mg/kg) Non-Carc	1.6E+01 s v out (mg/kg) Non-Carc
5-6 Aliphatics	3.1E+02	3.4E+04	4.7E+03	5.1E+05	2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	1.6E+03	2.2E+04	6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	1.5E+04	5.4E+05	6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	3.7E+03	2.3E+04	1.6E+06
>8-10 Aliphatics	1.4E+02	2.5E+04	4.3E+03	1.2E+04	1.8E+06
>8-10 Aromatics	1.0E+03	5.0E+02	5.9E+03	4.8E+03	2.5E+06
>10-12 Aliphatics	8.5E+01	2.0E+05	2.2E+04	1.2E+04	9.2E+06
>10-12 Aromatics	6.3E+02	8.0E+02	3.1E+04	4.8E+03	1.3E+07
>12-16 Aliphatics	3.8E+01	4.0E+06	1.0E+05	1.2E+04	4.4E+07
>12-16 Aromatics	2.9E+02	1.6E+03	1.5E+05	4.9E+03	6.2E+07
>16-21 Aliphatics	1.3E+01	1.6E+10	1.2E+07	2.4E+05	5.0E+09
>16-21 Aromatics	8.1E+01	3.8E+03	8.1E+05	3.6E+03	3.4E+08
>21-35 Aromatics	8.3E+00	3.0E+04	1.7E+07	3.6E+03	5.6E+09

	Fraction HQ(Ci) (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	1.2E-03	1.7E-04	6.6E-02	2.2E-05	1.5E-04
5-7 Aromatics	3.3E-05	1.1E-03	3.5E-01	1.4E-05	2.3E-03
>6-8 Aliphatics	1.2E-03	3.6E-05	1.5E-02	2.1E-05	3.5E-05
>7-8 Aromatics	1.0E-04	1.3E-03	3.4E-01	4.3E-05	7.9E-04
>8-10 Aliphatics	3.0E-01	5.4E-03	3.2E-02	2.4E-01	7.4E-05
>8-10 Aromatics	3.5E-02	3.3E-01	1.7E-01	7.0E-02	4.1E-04
>10-12 Aliphatics	4.9E-01	4.3E-04	4.0E-03	3.9E-01	9.3E-06
>10-12 Aromatics	1.0E-01	6.2E-01	2.0E-02	2.1E-01	4.7E-05
>12-16 Aliphatics	2.6E-02	9.6E-06	3.7E-04	2.1E-02	8.6E-07
>12-16 Aromatics	1.0E-02	3.0E-02	2.0E-03	2.0E-02	4.7E-06
>16-21 Aliphatics	6.2E-03	8.2E-10	1.1E-06	2.4E-04	2.6E-09
>16-21 Aromatics	6.8E-03	8.6E-03	9.9E-05	1.8E-02	2.4E-07
>21-35 Aromatics	1.5E-02	2.8E-04	5.0E-07	4.0E-02	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	1.1E+01 s lch (mg/kg)	1.6E+01 s v in (mg/kg)	1.8E+01 ss (mg/kg)	1.6E+01 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	3.8E-03
RBSL(HI=1) mg/kg	4.7E+03	1.7E+07	9.5E+03	4.8E+07

Tier 1-A Model Runs

Tier 1a - 7

CONSTRUCTION WORKER SCENARIO

	Csat	RBSL.R.11 s lch	RBSL.R.16 s v in	RBSL.R.16 ss	RBSL.R.18 s v out	RBSL.R.16 s v out
	(mg/kg)	(mg/kg) HQ=1	(mg/kg) HQ=1	(mg/kg) HQ=1	(mg/kg) HQ=1	(mg/kg) HQ=1
5-6 Aliphatics	3.1E+02	3.4E+04	1.9E+03	4.9E+05		2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	6.4E+02	2.1E+04		6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	6.0E+03	5.2E+05		6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	1.5E+03	2.2E+04		1.6E+06
>8-10 Aliphatic	1.4E+02	2.5E+04	1.8E+03	1.1E+04		1.8E+06
>8-10 Aromatic	1.0E+03	5.0E+02	2.4E+03	4.5E+03		2.5E+06
>10-12 Aliphatic	8.5E+01	2.0E+05	8.8E+03	1.1E+04		9.2E+06
>10-12 Aromatis	6.3E+02	8.0E+02	1.3E+04	4.6E+03		1.3E+07
>12-16 Aliphatic	3.8E+01	4.0E+06	4.2E+04	1.1E+04		4.4E+07
>12-16 Aromatis	2.9E+02	1.6E+03	5.9E+04	4.6E+03		6.2E+07
>16-21 Aliphatic	1.3E+01	1.6E+10	4.7E+06	2.3E+05		5.0E+09
>16-21 Aromatis	8.1E+01	3.8E+03	3.3E+05	3.4E+03		3.4E+08
>21-35 Aromatis	8.3E+00	3.0E+04	6.7E+06	3.4E+05		5.6E+09
Total						

	Fraction (mg/kg/mg/kg)	HQ(Ci) s lch	HQ(Ci) s v in	HQ(Ci) ss	HQ(Ci) s v out
5-6 Aliphatics	6.9E-03	1.0E-03	1.6E-01	1.3E-04	1.5E-04
5-7 Aromatics	1.6E-04	5.6E-03	1.6E-01	6.7E-05	2.3E-03
>6-8 Aliphatics	6.9E-03	2.1E-04	3.6E-02	1.2E-04	3.5E-05
>7-8 Aromatics	1.6E-04	2.0E-03	6.9E-02	6.5E-05	7.9E-04
>8-10 Aliphatics	4.1E-01	5.4E-03	7.8E-02	3.2E-01	7.4E-05
>8-10 Aromatics	4.8E-02	4.7E-01	4.3E-01	9.4E-02	4.1E-04
>10-12 Aliphatic	3.5E-01	4.3E-04	9.7E-03	2.7E-01	9.3E-06
>10-12 Aromatics	7.4E-02	4.6E-01	5.0E-02	1.4E-01	4.7E-05
>12-16 Aliphatic	3.7E-02	9.6E-06	9.0E-04	2.9E-02	8.6E-07
>12-16 Aromatics	1.4E-02	4.3E-02	4.9E-03	2.7E-02	4.7E-06
>16-21 Aliphatic	6.9E-03	8.2E-10	2.8E-06	2.7E-04	2.6E-09
>16-21 Aromatics	1.2E-02	1.6E-02	2.4E-04	3.2E-02	2.4E-07
>21-35 Aromatics	3.1E-02	2.8E-04	1.2E-06	7.9E-02	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11 s lch	RBSL.R.16 s v in	RBSL.R.16 ss	RBSL.R.18 s v out	RBSL.R.16 s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00	
RBSL(HI=1) mg/kg	4.9E+03	6.5E+05	8.9E+03	3.8E-03	1.0E+07

COMMERCIAL SCENARIO

	Csat	1.1E+01 s lch	1.6E+01 s v in	1.8E+01 ss	1.6E+01 s v out
	(mg/kg)	(mg/kg) Non-Carc	(mg/kg) Non-Carc	(mg/kg) Non-Carc	(mg/kg) Non-Carc
5-6 Aliphatics	3.1E+02	3.4E+04	4.7E+03	5.1E+05	2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	1.6E+03	2.2E+04	6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	1.5E+04	5.4E+05	6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	3.7E+03	2.3E+04	1.6E+06
>8-10 Aliphatics	1.4E+02	2.5E+04	4.3E+03	1.2E+04	1.8E+06
>8-10 Aromatics	1.0E+03	5.0E+02	5.9E+03	4.8E+03	2.5E+06
>10-12 Aliphatics	8.5E+01	2.0E+05	2.2E+04	1.2E+04	9.2E+06
>10-12 Aromatics	6.3E+02	8.0E+02	3.1E+04	4.8E+03	1.3E+07
>12-16 Aliphatics	3.8E+01	4.0E+06	1.0E+05	1.2E+04	4.4E+07
>12-16 Aromatics	2.9E+02	1.6E+03	1.5E+05	4.9E+03	6.2E+07
>16-21 Aliphatics	1.3E+01	1.6E+10	1.2E+07	2.4E+05	5.0E+09
>16-21 Aromatics	8.1E+01	3.8E+03	8.1E+05	3.6E+03	3.4E+08
>21-35 Aromatics	8.3E+00	3.0E+04	1.7E+07	3.6E+03	5.6E+09
Total					

	Fraction (mg/kg/mg/kg)	HQ(Ci) s lch	HQ(Ci) s v in	HQ(Ci) ss	HQ(Ci) s v out
5-6 Aliphatics	6.9E-03	1.0E-03	6.6E-02	1.3E-04	1.5E-04
5-7 Aromatics	1.6E-04	5.6E-03	4.8E-01	6.7E-05	2.3E-03
>6-8 Aliphatics	6.9E-03	2.1E-04	1.5E-02	1.2E-04	3.5E-05
>7-8 Aromatics	1.6E-04	2.0E-03	2.1E-01	6.5E-05	7.9E-04
>8-10 Aliphatics	4.1E-01	5.4E-03	3.2E-02	3.2E-01	7.4E-05
>8-10 Aromatics	4.8E-02	4.7E-01	1.7E-01	9.4E-02	4.1E-04
>10-12 Aliphatics	3.5E-01	4.3E-04	4.0E-03	2.7E-01	9.3E-06
>10-12 Aromatics	7.4E-02	4.6E-01	2.0E-02	1.4E-01	4.7E-05
>12-16 Aliphatics	3.7E-02	9.6E-06	3.7E-04	2.9E-02	8.6E-07
>12-16 Aromatics	1.4E-02	4.3E-02	2.0E-03	2.7E-02	4.7E-06
>16-21 Aliphatics	6.9E-03	8.2E-10	1.1E-06	2.7E-04	2.6E-09
>16-21 Aromatics	1.2E-02	1.6E-02	9.9E-05	3.2E-02	2.4E-07
>21-35 Aromatics	3.1E-02	2.8E-04	5.0E-07	7.9E-02	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	1.1E+01 s lch	1.6E+01 s v in	1.8E+01 ss	1.6E+01 s v out
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	
RBSL(HI=1) mg/kg	4.9E+03	4.8E+06	9.4E+03	3.8E-03	1.1E+07

Tier 1-A RBCA Model Runs

Tier 1a - 9 — CONSTRUCTION WORKER SCENARIO

	Csat (mg/kg)	RBSL.R.11 s lch (mg/kg) HQ=1	RBSL.R.16 s v in (mg/kg) HQ=1	RBSL.R.16 ss (mg/kg) HQ=1	RBSL.R.18 s v out (mg/kg) HQ=1
5-6 Aliphatics	3.1E+02	3.4E+04	1.9E+03	4.9E+05	2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	6.4E+02	2.1E+04	6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	6.0E+03	5.2E+05	6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	1.5E+03	2.2E+04	1.6E+06
>8-10 Aliphatic	1.4E+02	2.5E+04	1.8E+03	1.1E+04	1.8E+06
>8-10 Aromatic	1.0E+03	5.0E+02	2.4E+03	4.5E+03	2.5E+06
>10-12 Aliphatic	8.5E+01	2.0E+05	8.8E+03	1.1E+04	9.2E+06
>10-12 Aromatics	6.3E+02	8.0E+02	1.3E+04	4.6E+03	1.3E+07
>12-16 Aliphatic	3.8E+01	4.0E+06	4.2E+04	1.1E+04	4.4E+07
>12-16 Aromatics	2.9E+02	1.6E+03	5.9E+04	4.6E+03	6.2E+07
>16-21 Aliphatis	1.3E+01	1.6E+10	4.7E+06	2.3E+05	5.0E+09
>16-21 Aromatic	8.1E+01	3.8E+03	3.3E+05	3.4E+03	3.4E+08
>21-35 Aromatis	8.3E+00	3.0E+04	6.7E+06	3.4E+03	5.6E+09

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	1.8E-03	1.9E-04	1.6E-01	3.1E-05	1.5E-04
5-7 Aromatics	4.0E-05	1.1E-03	6.1E-02	1.6E-05	2.3E-03
>6-8 Aliphatics	7.7E-03	1.8E-04	3.6E-02	1.3E-04	3.5E-05
>7-8 Aromatics	2.6E-04	2.5E-03	1.7E-01	1.0E-04	7.9E-04
>8-10 Aliphatics	3.2E-01	5.4E-03	7.8E-02	2.4E-01	7.4E-05
>8-10 Aromatic	5.6E-02	4.2E-01	4.3E-01	1.1E-01	4.1E-04
>10-12 Aliphatic	4.2E-01	4.3E-04	9.7E-03	3.1E-01	9.3E-06
>10-12 Aromatic	1.1E-01	5.3E-01	5.0E-02	2.1E-01	4.7E-05
>12-16 Aliphatic	2.1E-02	9.6E-06	9.0E-04	1.5E-02	8.6E-07
>12-16 Aromatics	1.2E-02	2.8E-02	4.9E-03	2.2E-02	4.7E-06
>16-21 Aliphatic	9.0E-03	8.2E-10	2.8E-06	3.3E-04	2.6E-09
>16-21 Aromatics	1.8E-02	1.8E-02	2.4E-04	4.4E-02	2.4E-07
>21-35 Aromatis	2.2E-02	2.8E-04	1.2E-06	5.5E-02	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11 s lch (mg/kg)	RBSL.R.16 s v in (mg/kg)	RBSL.R.16 ss (mg/kg)	RBSL.R.18 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/g	3.7E+03	9.7E+05	8.4E+03	4.8E+07

COMMERCIAL SCENARIO

	Csat (mg/kg)	1.1E+01 s lch (mg/kg) Non-Carc	1.6E+01 s v in (mg/kg) Non-Carc	1.8E+01 ss (mg/kg) Non-Carc	1.6E+01 s v out (mg/kg) Non-Carc
5-6 Aliphatics	3.1E+02	3.4E+04	4.7E+03	5.1E+05	2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	1.6E+03	2.2E+04	6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	1.5E+04	5.4E+05	6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	3.7E+03	2.3E+04	1.6E+06
>8-10 Aliphatics	1.4E+02	2.5E+04	4.3E+03	1.2E+04	1.8E+06
>8-10 Aromatics	1.0E+03	5.0E+02	5.9E+03	4.8E+03	2.5E+06
>10-12 Aliphatics	8.5E+01	2.0E+05	2.2E+04	1.2E+04	9.2E+06
>10-12 Aromatics	6.3E+02	8.0E+02	3.1E+04	4.8E+03	1.3E+07
>12-16 Aliphatics	3.8E+01	4.0E+06	1.0E+05	1.2E+04	4.4E+07
>12-16 Aromatics	2.9E+02	1.6E+03	1.5E+05	4.9E+03	6.2E+07
>16-21 Aliphatics	1.3E+01	1.6E+10	1.2E+07	2.4E+05	5.0E+09
>16-21 Aromatics	8.1E+01	3.8E+03	8.1E+05	3.6E+03	3.4E+08
>21-35 Aromatics	8.3E+00	3.0E+04	1.7E+07	3.6E+03	5.6E+09

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	1.8E-03	1.9E-04	6.6E-02	3.1E-05	1.5E-04
5-7 Aromatics	4.0E-05	1.1E-03	3.5E-01	1.6E-05	2.3E-03
>6-8 Aliphatics	7.7E-03	1.8E-04	1.5E-02	1.3E-04	3.5E-05
>7-8 Aromatics	2.6E-04	2.5E-03	3.4E-01	1.0E-04	7.9E-04
>8-10 Aliphatics	3.2E-01	5.4E-03	3.2E-02	2.4E-01	7.4E-05
>8-10 Aromatics	5.6E-02	4.2E-01	1.7E-01	1.1E-01	4.1E-04
>10-12 Aliphatics	4.2E-01	4.3E-04	4.0E-03	3.1E-01	9.3E-06
>10-12 Aromatics	1.1E-01	5.3E-01	2.0E-02	2.1E-01	4.7E-05
>12-16 Aliphatics	2.1E-02	9.6E-06	3.7E-04	1.5E-02	8.6E-07
>12-16 Aromatics	1.2E-02	2.8E-02	2.0E-02	2.2E-02	4.7E-06
>16-21 Aliphatics	9.0E-03	8.2E-10	1.1E-06	3.3E-04	2.6E-09
>16-21 Aromatics	1.8E-02	1.8E-02	9.9E-05	4.4E-02	2.4E-07
>21-35 Aromatics	2.2E-02	2.8E-04	5.0E-07	5.5E-02	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	1.1E+01 s lch (mg/kg)	1.6E+01 s v in (mg/kg)	1.8E+01 ss (mg/kg)	1.6E+01 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	3.7E+03	1.4E+07	8.9E+03	4.8E+07

Tier 1-A RBCA Model Runs

Tier 1a - 11 — CONSTRUCTION WORKER SCENARIO

	Csat (mg/kg)	RBSL.R.11 s lch (mg/kg) HQ=1	RBSL.R.16 s v in (mg/kg) HQ=1	RBSL.R.16 ss (mg/kg) HQ=1	RBSL.R.18 s v out (mg/kg) HQ=1	RBSL.R.16 s v out (mg/kg) HQ=1
5-6 Aliphatics	3.1E+02	3.4E+04	1.9E+03	4.9E+05	2.0E+06	
5-7 Aromatics	1.6E+03	1.4E+02	6.4E+02	2.1E+04	6.7E+05	
>6-8 Aliphatics	2.2E+02	1.6E+05	6.0E+03	5.2E+05	6.3E+06	
>7-8 Aromatics	1.2E+03	3.8E+02	1.5E+03	2.2E+04	1.6E+06	
>8-10 Aliphatic	1.4E+02	2.5E+04	1.8E+03	1.1E+04	1.8E+06	
>8-10 Aromatics	1.0E+03	5.0E+02	2.4E+03	4.5E+03	2.5E+06	
>10-12 Aliphatis	8.5E+01	2.0E+05	8.8E+03	1.1E+04	9.2E+06	
>10-12 Aromats	6.3E+02	8.0E+02	1.3E+04	4.6E+03	1.3E+07	
>12-16 Aliphatis	3.8E+01	4.0E+06	4.2E+04	1.1E+04	4.4E+07	
>12-16 Aromatis	2.9E+02	1.6E+03	5.9E+04	4.6E+03	6.2E+07	
>16-21 Aliphatis	1.3E+01	1.6E+10	4.7E+06	2.3E+05	5.0E+09	
>16-21 Aromatis	8.1E+01	3.8E+03	3.3E+05	3.4E+03	3.4E+08	
>21-35 Aromats	8.3E+00	3.0E+04	6.7E+06	3.4E+03	5.6E+09	

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	5.2E-03	6.3E-04	1.6E-01	9.1E-05	1.5E-04
5-7 Aromatics	1.2E-04	3.4E-03	1.3E-01	4.7E-05	2.3E-03
>6-8 Aliphatics	5.2E-03	1.3E-04	3.6E-02	8.6E-05	3.5E-05
>7-8 Aromatics	2.2E-04	2.3E-03	1.0E-01	8.6E-05	7.9E-04
>8-10 Aliphatic	2.6E-01	5.4E-03	7.8E-02	1.9E-01	7.4E-05
>8-10 Aromatic	3.8E-02	3.1E-01	4.3E-01	7.1E-02	4.1E-04
>10-12 Aliphatis	4.9E-01	4.3E-04	9.7E-03	3.6E-01	9.3E-06
>10-12 Aromatis	1.2E-01	6.3E-01	5.0E-02	2.3E-01	4.7E-05
>12-16 Aliphatis	1.3E-02	9.6E-06	9.0E-04	9.7E-03	8.6E-07
>12-16 Aromatis	1.3E-02	3.2E-02	4.9E-03	2.3E-02	4.7E-06
>16-21 Aliphatis	1.3E-02	8.2E-10	2.8E-06	4.8E-04	2.6E-09
>16-21 Aromatis	1.4E-02	1.6E-02	2.4E-04	3.5E-02	2.4E-07
>21-35 Aromats	3.3E-02	2.8E-04	1.2E-06	8.0E-02	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	RBSL.R.11 s lch (mg/kg)	RBSL.R.16 s v in (mg/kg)	RBSL.R.18 ss (mg/kg)	RBSL.R.16 s v out (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/g	4.1E+03	7.0E+05	8.4E+03	1.8E+07

COMMERCIAL SCENARIO

	Csat (mg/kg)	s lch 1.1E+01 (mg/kg) Non-Carc	s v in 1.6E+01 (mg/kg) Non-Carc	ss 1.8E+01 (mg/kg) Non-Carc	s v out 1.6E+01 (mg/kg) Non-Carc
5-6 Aliphatics	3.1E+02	3.4E+04	4.7E+03	5.1E+05	2.0E+06
5-7 Aromatics	1.6E+03	1.4E+02	1.6E+03	2.2E+04	6.7E+05
>6-8 Aliphatics	2.2E+02	1.6E+05	1.5E+04	5.4E+05	6.3E+06
>7-8 Aromatics	1.2E+03	3.8E+02	3.7E+03	2.3E+04	1.6E+06
>8-10 Aliphatics	1.4E+02	2.5E+04	4.3E+03	1.2E+04	1.8E+06
>8-10 Aromatics	1.0E+03	5.0E+02	5.9E+03	4.8E+03	2.5E+06
>10-12 Aliphatics	8.5E+01	2.0E+05	2.2E+04	1.2E+04	9.2E+06
>10-12 Aromatics	6.3E+02	8.0E+02	3.1E+04	4.8E+03	1.3E+07
>12-16 Aliphatics	3.8E+01	4.0E+06	1.0E+05	1.2E+04	4.4E+07
>12-16 Aromatics	2.9E+02	1.6E+03	1.5E+05	4.9E+03	6.2E+07
>16-21 Aliphatics	1.3E+01	1.6E+10	1.2E+07	2.4E+05	5.0E+09
>16-21 Aromatics	8.1E+01	3.8E+03	8.1E+05	3.6E+03	3.4E+08
>21-35 Aromatics	8.3E+00	3.0E+04	1.7E+07	3.6E+03	5.6E+09

	Fraction (mg/kg/mg/kg)	HQ(Ci)	HQ(Ci)	HQ(Ci)	HQ(Ci)
5-6 Aliphatics	5.2E-03	6.3E-04	6.6E-02	9.1E-05	1.5E-04
5-7 Aromatics	1.2E-04	3.4E-03	3.8E-01	4.7E-05	2.3E-03
>6-8 Aliphatics	5.2E-03	1.3E-04	1.5E-02	8.6E-05	3.5E-05
>7-8 Aromatics	2.2E-04	2.3E-04	3.1E-01	8.6E-05	7.9E-04
>8-10 Aliphatics	2.6E-01	5.4E-03	3.2E-02	1.9E-01	7.4E-05
>8-10 Aromatics	3.8E-02	3.1E-01	1.7E-01	7.2E-02	4.1E-04
>10-12 Aliphatics	4.9E-01	4.3E-04	4.0E-03	3.6E-01	9.3E-06
>10-12 Aromatics	1.2E-01	6.3E-01	2.0E-02	2.3E-01	4.7E-05
>12-16 Aliphatics	1.3E-02	9.6E-06	3.7E-04	9.7E-03	8.6E-07
>12-16 Aromatics	1.3E-02	3.2E-02	2.0E-03	2.3E-02	4.7E-06
>16-21 Aliphatics	1.3E-02	8.2E-10	1.1E-06	4.8E-04	2.6E-09
>16-21 Aromatics	1.4E-02	1.6E-02	9.9E-05	3.5E-02	2.4E-07
>21-35 Aromatics	3.3E-02	2.8E-04	5.0E-07	8.0E-02	1.5E-09
Total	1.0E+00				

SV in Calculation based on 1.0 percent foundation cracks

	s lch 1.1E+01 (mg/kg)	s v in 1.6E+01 (mg/kg)	ss 1.8E+01 (mg/kg)	s v out 1.6E+01 (mg/kg)
HI	1.0E+00	1.0E+00	1.0E+00	1.0E+00
RBSL(HI=1) mg/kg	4.1E+03	5.2E+06	8.9E+03	1.8E+07